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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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THE INDUSTRIAL BREAKDOWN IN RUSSIA.

By ALLAN MONKHOUSE, Junr., A.M.I.E.E., A.Am.I.E.E.

"DURING the ten or fifteen years that preceded the outbreak of the present war Russia was one of those countries which was steadily and rapidly developing its manufacturing industries. The outbreak of war only assisted in still further boosting the efforts of the Russian manufacturers, who made every effort to take advantage of their being cut off from cheap German competition, to develop new Russian home industries. The enormous existing works were enlarged, and scores of new works were put into operation. The great Putiloff works in Petrograd were extended to employ 30,000 hands. The amalgamated Sormovo and Kolomna companies employed an even greater number of men in their three works at Kolomna, Sormovo and Kulibak. The Imperial Government had almost completed two large new arsenals, one the Tamboff gun works and the other the Tsaritsin gun works. The Imperial small arms factories at Tula had been greatly extended. The Bransk engineering works plants, the Helferich Sadet Company, the Moscow metal works, the Petrograd Metal-working Company, the Eshoffski works, the International Harvester Company's works at Lubertsi, and the Singer works at Podolsk, may be mentioned amongst the larger works which had made improvements to their plants to cope with the enormous war demands.

In the electrical engineering industry the Russian Electrical Company "Dynamo" (a company formed in 1913, representing Westinghouse interests) had more than doubled their works capacity in Moscow, and opened two other new works for making electrical supplies. The various cable-making firms, including the Russian Cable and Metal Rolling Company, the Kolchugin Cable Company, and the Vishnarkoff, Shamshin, Alexieff Company, in Moscow, and the United Cable Works in Petrograd, had some of them increased their production to as much as six times what it was previously. The General Electrical Company of Russia, having evacuated from Riga, had put down a new shop at Harkoff which, when equipped, was to employ 10,000 hands. The Russian Siemens and Halske Company had just completed a large new plant at Nijni Novgorod for the manufacture of telephone and telegraph apparatus.

All the great Ural works—the Listvenski works, the Upper Issetski works, the Saladovnikoff works, the Perm gun works and the Zlaloustmski works—were engaged on extensive plant enlargements. The shipyards of Nikolaeffsk and Mariopol in the south and Petrograd in the north were experiencing times that could be compared with those now being experienced in our own yards. A large naval yard had been opened up at Tornopal and great port works undertaken at Savastopol and Odessa. The Hughesoffski works and the other great steel and iron works of the Ekaterinoslav district and the Urals could not keep pace with the enormous demands for their products. The new "Electrostahl" Company near Moscow and the Makaeffa works were putting down large new electric steel furnaces for making special high-grade steels by the most modern electric processes. The Kusnitzoff, Raboushinski Company were completing an enormous works near Moscow to build motor transport wagons, and another works of a similar nature was being built at Mitishi, near Moscow.

Smaller works were being put down all over the country to manufacture necessaries which had previously been imported from abroad, including electrical apparatus and switchgear; magnetos, paints, chemicals, X-ray apparatus, explosives, lubricating oils, &c. Manufacturers were looking ahead to the permanent building-up of a great Russian home industry. The great textile factories of Yaroslav Orekova, Ramenski, Shusselberg, Kostroma, Tver, Kinishma and Moscow were working at full pressure. The absence of foreign raw cotton was being largely met by the rapidly increasing supplies from the cotton fields of Central Asia. The working people were in receipt of a wage which was more than proportional to the increased cost of living since 1914, and the conditions of labour were improving.

In this country one hears much of the oppression of the peasants in Russia under the old *regime*, but speaking generally, men who have superintended labour in both England and Russia confidently assert that the protection afforded the men by factory Acts and the general conditions under which the workers worked in the large works left them quite as well off as their British brethren. Furthermore, it is unquestionably a fact that before the revolution the workpeople were more or less satisfied with their conditions of employment. It is an error to think that the revolution, at its outbreak, was carried into effect by the workmen of the works and factories. Britishers who were personal spectators of the events that deposed the Czar, and active members of the Militia which restored order in the first days that followed, unanimously confirm the oft-repeated statement that the revolution was originated by the Duma and the garrisons of Petrograd and Moscow, backed by the usual complement of students and idealists (always to be found in a movement of this sort), and that the workers had but very little share in it. In those first triumphant processions held early in March, 1917, it was the soldiers and officers of the garrisons and the revolutionary organisations composed of the middle and educated classes (*intelligensia*) which figured most conspicuously—not the industrial workers who were for the most part interested spectators.

Hardly a week had passed, however, before the Soviet (or Advisory Council) of soldiers' and workmen's deputies had reassembled and begun to make its pressure felt in its first quarrels with the new Provisional Government. The middle of April saw the formation in most of the larger works of workmen's committees which were elected by the workpeople to represent their interests in all dealings with the managements of the works. These committees also elected representatives to the newly-forming trade unions and to the Soviets, and consequently became the mediums of intercourse between those assemblies and the employers. Their power became rapidly greater, so that by the end of May the employers found themselves compelled to agree to working hand in hand with these committees and being frequently subject to their decisions, especially in matters relating to engaging and discharging employees and rates of wages. No works were permitted to engage men except those recommended by the local unions.

As the unions found themselves becoming stronger, their demands began to increase. Wages rose rapidly beyond all proportion and conflicts between workpeople and employers became the rule in almost every works. The employers possessed an Employers' Association which had been in existence for several years, but which did not seem able to do anything to back up the employers as a whole against any of the ever-increasing and entirely outrageous demands of the workers. This association only succeeded in employing its organisation to distribute an unlimited amount of utterly useless printed matter and forms for filling up, giving unnecessary details of production, &c.

A workmen's arbitration court was formed under the auspices of the Soviet, and all conflicts were referred to it. These courts were composed of working men arbitrators, most of whom had only the slightest idea of the work they were doing, although, on the other hand, their lack of knowledge was usually more than accounted for by the Jewish lawyers who invariably presided. Nevertheless, it is only fair to state that the decisions of these courts were very reasonable. The trouble was, however, that the representatives of the men were invariably sent to the courts with instructions from the general meetings of workpeople not to agree to any compromises at all of any sort, and consequently in the majority of cases the workpeople quite disregarded the courts' decisions unless they were made absolutely in their favour. Not infrequently the workmen's committees signed agreements with the works administration lasting two or three months, yet they would appear a fortnight later quite without hesitation disregarding their agreement and forcibly making new excessive demands. It may here be noted that one of the most striking things in the behaviour of the working people since the revolution has been their complete disregard for agreements and their ignoring of all the principles of rule by majority.

As the summer wore on the strength of the Bolshevik movement increased steadily, and it was about this time that it began to become evident that some strong influence was at work endeavouring to undermine Russian industry. There seems little question that Germany had begun to lend a backing to the extreme Bolshevik party, knowing that their extreme programme would cripple Russia much more effectively than many months production of German munitions.

During this period works managers and labour superintendents who were compelled almost weekly to visit the Soviet and trade union officials, in connection with works matters, almost invariably found them to be Jews, many of whom had left England to evade military service and consequently bore a distinct grudge against that country. It was noticeable that in these organisations no opportunity was missed to denounce "imperialistic England and capitalistic America." Several cases are on record where these men were distinctly and openly pro-German. The majority of them held their positions in view of their claim to have been trade union members in England, and consequently they were welcomed as "instructors" (this is the actual word the Soviet employed) in trade union matters. To illustrate this, the case may be mentioned of one of the "instructor-arbitrators" on piece-work prices for machine shop men, who was recognised (much to his confusion) whilst laying down the law on machine-work rates. In the capacity of hotel barber at one of the largest hotels in London he had shaved the British engineer who recognised him, scores of times.

The workmen's committees gradually became universal even in the smallest establishments. In many works they succeeded in displacing the management entirely and taking complete control themselves. Not infrequently managers and foremen were subjected to indignities, being wheeled out of the works premises on a wheelbarrow loaded with filth and refuse. Several British and American citizens suffered this fate, but in almost every case a few days saw the committees requesting their return. A good tale is told of one American, manager of one of the largest American works in Russia, who, when requested to return, replied that he was willing to do so on condition that the committee brought the same wheelbarrow down to his residence and wheeled him back to the works with suitable ceremony.

As Bolshevik influence increased it became quite impossible for the works administration to act without placing themselves entirely in the hands of the works committee. Neither requisitions addressed to one of the central committee controlling the distribution of raw materials, nor applications to the military tribunals for exemptions, &c., were valid without the signature of the works committee. Even the obtaining of these signatures was a disorganising factor. It frequently took half an hour to get four men to sign as many letters. At one British-owned works, the president of the works committee was an illiterate plumber and had to be instructed in making his signature each time. This man, however, was blessed with a good memory and used to memorise parts of the inflammatory speeches made in the Soviet against the employers and capitalists, and these he used to recite with great effect at works meetings, all too often himself not fully understanding what he was saying.

Almost every week the works stood a day or two. The men were making such enormous wages that one day's loss of pay did not embarrass them, and consequently every excuse was accepted to declare a holiday. The anniversary of almost every notable event in Russia's revolutionary history, and not a few of the days memorable in the French revolution, were declared holidays. The great religious feasts were also observed as holidays, and when Saturday and Monday became intervening days between two holidays, they were also declared holidays, as the committees would claim that it was not worth

while re-opening for one day. Sometimes a compromise was arranged with the men that if they failed to work on an intervening day like this, they should work off the lost time during the following week, or on the next week-end. This arrangement allowed the men to return to their villages when there were three consecutive days' holiday and secure for themselves fresh stocks of provisions, because the shortage of food was acute almost from the commencement of the revolution.

The great fight in November, when the Bolsheviks forcibly seized the power from the Provisional Government, only produced a more intense antagonism between employers and men, and from that time the workers' committees openly declared their intention of seizing all works property. The Soviet began to draft a decree declaring all works to be national property, whilst the employers were making every endeavour to save what they could from the wreck of their works.

The final blow came with the seizure of the banks by the Bolshevik authorities. All money lying in depositors' accounts was "arrested" and depositors were permitted to draw only 150 roubles per week, and, moreover, to obtain this entailed hours of waiting in queue. No money was permitted to be paid out to the works except for paying wages, and this only on presentation of a schedule showing the exact amount earned by every employee. This schedule was countersigned by the works committee, the works administration, and the local commissioner of labour-finance, after which it was presented to the Central Commission of finance who gave permission for the Government bank to pay out the money. The obtaining of all these signatures could not be accomplished in less than three or four days, and consequently almost every week-end saw labour disturbances caused by delay in obtaining money for wages. This delay was naturally credited to the employers as an act of provocation, but was unquestionably frequently intentional on the part of the Bolshevik authorities because the Government banks had no funds to pay out with. The complete distrust with which the populace looked upon the Government resulted in no cash deposits being made in the Government savings banks or the private banks, and thus the Government bank was robbed of those channels through which it previously received back its cash funds. New paper money was being printed in Petrograd as rapidly as printing presses working day and night could turn it out.

It was practically impossible to obtain money for purchasing raw materials; nevertheless manufacturers who found their raw material supplies gone and who consequently announced their intention of closing down were denounced as "provocators" and "sabotagniks," and in many cases had their works seized and were themselves arrested and held by the workmen until they signed cheques (or otherwise obtained huge sums of money) to pay their practically unemployed workpeople. When a shutdown became inevitable, due to complete absence of fuel or raw materials, the workmen demanded and usually forcibly obtained three months' wages in advance.

In many works the workers demanded enormous bonuses from the surplus profits they claimed the manufacturers had made during the war. Many works which had with difficulty hung on until January of this year were finally compelled to close by an absurd decree of the Soviet calling upon all employers to pay an increase of approximately 26 per cent. all round, to date from October 1. By the end of January practically all the small works and the majority of the larger works were shut down. The cancellation of all war orders by a decree of the Soviet meant the shutting down of half the machine shops in the country.

The state into which the machine shops under committee management got was too appalling for words. The machines—many thousands of modern English and American tools introduced since the outbreak of war—were in a filthy state and apparently no attempt was made to compel the machine men to even wipe over their machines. Breakages were evident everywhere, due to misuse and rank carelessness, and yet no attempt at repairs was evident. All discipline had simply disappeared and observations showed that machine tools were only performing useful work four or five hours out of the eight (the Soviets had introduced an 8-hour day). Regularly tools stood whilst whole gangs of men engaged in political arguments with their new committee elected foremen.

Piece-work was previously the general rule in Russia, and experience had shown that this was the only way to secure production in a country where the workers as a whole came from the uneducated and oppressed peasant classes, and did not find themselves in any way bound to study the interests of their employers. The unions are now insisting on the abolition of piece-work and the substitution of an absurdly high day rate. All employees are grouped under trades for which minimum rates are set. For a man to become a member of the trades union it is not necessary for him to produce any certificate of having served his apprenticeship, thus it was frequently necessary for employers to pay quite useless lads of 18 years of age a full trademan's wage, although it was quite obvious they had had no training.

What has been said is perhaps enough to indicate the appalling condition of the works in Russia under workmen's committee control. Sufficient to add that the railways were never worse, and consequently transport has completely broken down.

Before closing, it may be mentioned that in the majority of works the junior staff—draughtsmen, tracers, chargehands, timekeepers, &c.—either formed their own unions and committees and worked in conjunction with the men committees, or actually joined the men, making demands equally impossible as the men's.

In conclusion it is perhaps necessary to again emphasise the fact that there is now little or no doubt that the absurd legislation and Acts of the Soviets and unions, which have so successfully disorganised Russian industry and demoralised Russia's workmen, were inspired by German brains and German money. Germany knew that by supporting Lenin and his party she could introduce a cleverly-developed piece of war apparatus which would wreck a great nation much more effectively than all the flame throwers or Zeppelins that German devilhood ever invented. Having accomplished her aim, Imperial Germany cannot but denounce the anarchy which now exists in Russia, a condition which cannot even be called Socialism by any stretching of the meaning of the word. Unquestionably the people of Russia are now heartily tired of Bolshevism and will welcome any power that will come in and save them. Such an expedition is being undertaken, and it is only to be hoped that it will be sufficiently powerful both militarily and technically to accomplish the stupendous task before it and save the suffering people of Russia.

WIND PRESSURE ON TALL CHIMNEYS.

THE erection of the lofty chimney of Saganoseki by the Weber Chimney Company, of Chicago, has given Professor Omori the opportunity of carrying out some observations on the movement to which the top of the chimney is submitted by wind pressure. These are of considerable interest, as they furnish the means of determining the degree of stability possessed by tall columns having an oscillation period of more than 2 seconds. In the case of the Saganoseki chimney, the material used is ferro-concrete, a material that will give to the completed structure a degree of stability differing in several important respects from that attaching to similar designs in brick or stone, mainly in consequence of the more slender form and thinner walls, possible with reinforced concrete. If we have two columns of equal height and section, one solid and the other hollow, the seismic stability of the hollow column is always greater than that of the solid, and in the case of very thin walls, the relative stability in the two cases approaches 2:1. This is by no means obvious, and Professor Omori explains the apparent anomaly by pointing out that the seismic destructive force is equivalent to the product of the mass of a given structure multiplied by the maximum acceleration of the earthquake motion. Hence the destructive force which is proportional to the mass, and which is resisted by the tensile strength of the section of fracture, is greater for the solid than the hollow column, the increase of the mass in the former being more effective than the decrease of the sectional area in the latter. Since the diminished area presented to the wind, due to reduction of diameter, and the economy of material in the structure are other factors that give a manifest advantage to the use of ferro-concrete in the place of brick, the substitution of this form is proceeding apace, and Professor Omori by demonstrating the reliability of reinforced concrete has rendered no slight service, and one that cannot be overlooked here, though it may be even better appreciated in earthquake-shaken countries.

The shaft which is the scene of the present investigation is the loftiest structure of the kind in the world, reaching a height of 550 ft. above the foundation pier. It stands on a hard Paleozoic formation whose seismic movement would probably be of less intensity than 500 mm./sec.^{2}, even in the case of a destructive earthquake originating in the neighbourhood. The base is about 450 ft. above sea-level, and the top reaching therefore to a height of 1,000 ft. must experience a much greater wind velocity than that registered at the surface. The effect was sufficiently patent during the observations, and it is no exaggeration to assume that in time of storms the wind velocity at the top will be twice that at the base. The details of the structure and general arrangement are shown in Figs. 1 to 5 on the opposite page, and the tapering form is clearly indicated in the following table:—

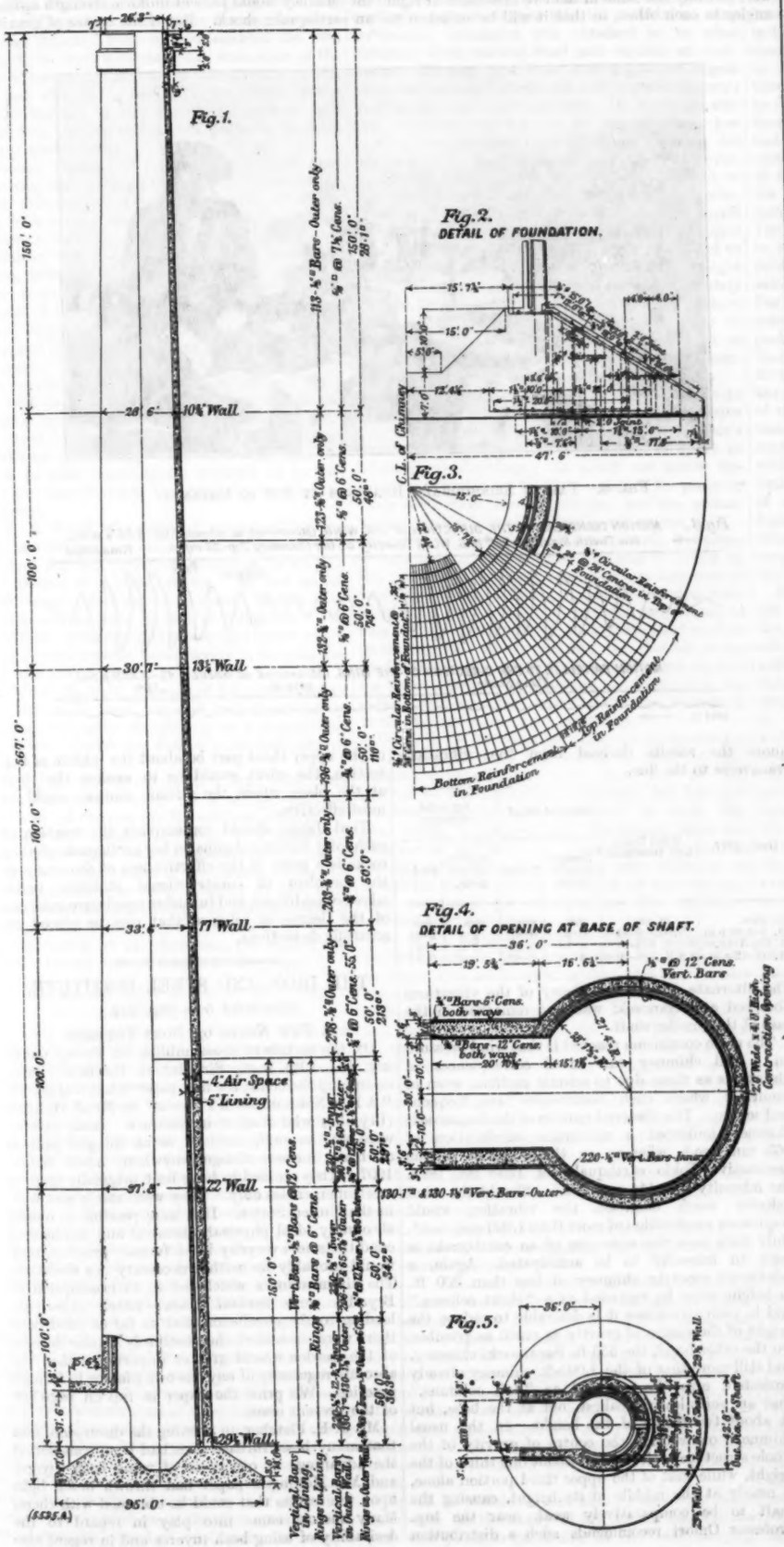
Height above Ground.	External Diameter.	Wall Thickness.	Height above ground of Centre of Gravity of each Portion.	Volume.
	ft. in.	in.	ft.	cub. ft.
Top ..	27 5	7	469·4	9,437
400 ft. ..	28 6	10½	347·7	8,932
300 ,, ..	30 7	13½	247·2	12,206
200 ,, ..	33 6	17	147·0	17,377
100 ,, ..	37 8	22	46·6	25,700
Base ..	42 8	29½	—	—
Total ..		—	—	73,652

The foundation, composed of reinforced concrete, is circular, 17 ft. in height and 95 ft. in diameter. Its weight is 4,714 tons, of which 4,603 tons are concrete, having the composition of 1:2:3·5, and the remaining 111 tons steel. The total weight of the main shaft is 4,852 tons, the reinforcement consisting of corrugated Johnson bars embedded in the concrete at the depth of 3 in. from the surface accounting for 316 tons. The total weight of the whole is therefore 9,139 tons, the pressure exerted by the main shaft being 3 tons per square foot, and the centre of gravity of the whole is 194·2 ft. from the ground or about $\frac{2}{3}$ of the height of the structure.

No external staging was erected, the materials and workmen were carried up by means of an elevator supporting a scaffolding 12 ft. by 12 ft., which at suitable intervals could be stayed against the interior wall of the chimney. The effectiveness of the arrangement is shown by the fact that the main shaft was completely erected in 190 days. This staging and its supports had not been removed prior to the observations, but could not have sensibly interfered with the vibration of the chimney shaft as the total weight was only 70 tons. Of more importance may have been the flue opening at the base, having a direction nearly W.N.W.–E.S.E., approximately parallel to that of the prevailing winds. The height of the flue is 31 ft. with a wall thickness of 3 ft. 6 in., and the opening at the base is 20 ft. in width with a semi-circular top of 10 ft. radius. The effect of this gap in the masonry is not negligible, and it is a little unfortunate that the range in the direction of the wind during the observations was too limited to permit fuller investigation.

The registering instruments consisted of two single component horizontal vibration recorders, one having half the sensitiveness of the other, each to be used according to the force of the wind. These instruments, which will be seen mounted on the shaft, in Fig. 6, page 336, were oriented so as to indicate the vibration either in a radial or tangential direction. Two positions were occupied at the top of the concrete shaft, one marked A, Fig. 7, used most frequently and always in times of high wind, was

WIND PRESSURE ON TALL CHIMNEYS.



vertically above the junction of the shaft with the steel concrete flue; the other, B, used in times of light winds, occupied a S.S.W. position. The variation in the force of the wind during the five days throughout which the observations were continued was considerable. On the first day a stormy gale with a velocity of 24 m. per second was recorded on a Robinson anemometer; then followed a period of three days with light airs, in which the velocity did not exceed 7 m. per second, but on the last day the weather was very strong, and the wind had the force of a hurricane, velocities of 35 m. per second, or 78 miles an hour, being registered. The directions of the wind are not recorded further than that they coincide with the direction of the flue and that the air circulation about the chimney top was of a complicated character.

The excursions to and fro' of the top of the shaft as registered on the automatic records are reproduced on a much reduced scale in Fig. 8. The upper diagram shows the motion transverse to the direction of the wind at the time of greatest velocity during the storm on December 26. The lower, the motion parallel to the direction of the wind about half an hour later. The difference in amplitude is the most striking feature. It was so pronounced that observers on the top of the column were sensible of the greater oscillation in the direction of the component at right angles to the wind's direction, than in that parallel to the wind's motion. The explanation offered by Professor Omori is scarcely convincing. He attributes the peculiar behaviour to the pressure of the wind bending the column, rendering it difficult for the latter to oscillate. He refers by way of analogy to the case of a flexible bamboo stick in a stream, which does not oscillate freely against the running water but is easily thrown into transverse movement. It must be remembered that the angle through which the column is bent, supposing it to move as one piece, is only about 30 seconds of arc, and if this damping action of the wind were real we should have expected a greater variation in the time of vibration than is shown in the diagram. The constancy of period in winds of all strengths is as remarkable as the variation in amplitude. Moreover, in the following table, in which is summarised the results of the five days' observations, this excessive motion in the transverse direction is not maintained. With small wind velocities, the motion parallel to the wind exceeds that in a transverse direction. A comparison between the results on the 22nd and 26th suggests that the motion on the latter date is too small. In another table, however, too long to quote, it would seem that the 20-mm. motion on the 22nd is a maximum and not an average excursion.

Table showing Vibration of Column Normal to the Direction of Wind.

Date, Dec., 1916.	Wind Velocity.	Range of Motion.	Complete Period.
h. m.	m. per sec.	mm.	sec.
Dec.	6·9	0·18	2·55
23, 9	6·7	0·13	2·58
	5·5	0·17	2·55
23, 2 15 p.m.	4·5	0·14	2·54
24, 2 30 p.m.	1·0	0·13	2·53
24, 10 0 a.m.	4·5	0·46	2·56
25, 11 0 a.m.	1·8	0·72	2·54
26, 3 0 p.m.	35·0	186·00	2·56

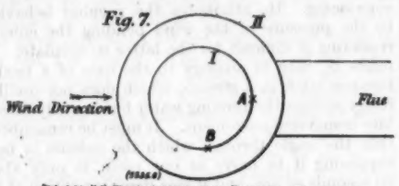
Vibration of Column Parallel to the Direction of Wind.

Date, Dec., 1916.	Wind Velocity.	Range of Motion.	Complete Period.
Dec. h. m.	m. per sec.	mm.	sec.
22, 3 30 p.m.	22·0	20·00	2·56
24, 1 0 p.m.	1·0	0·47	2·52
24, 11 0 a.m.	1·0	0·24	2·53
26, 8 30 p.m.	35·0	20·00	2·54

Another fact of great importance made manifest by these figures is the rapid increase in amplitude with the augmentation of the wind's velocity. The simple formula that suggests that pressure varies as the square of the velocity does not hold here. With a velocity of 6 m./sec. the excursion is quite insignificant; at 24 m./sec. the complete range or double altitude is less than an inch; with the hurricane force of 35 m./sec. the motion amounted to nearly 8 in. Professor Omori is quite justified in

asserting that with a wind velocity of 50 m./sec.—a velocity occasionally reached in gusts in this country—the chimney top would move at least 15 in. The period of oscillation in either direction does not vary with the amplitude, at least within the range of the present experiment, "probably because the motion was well below the elastic limit of the reinforced concrete structure." The mean period of the transverse oscillation, 2·55 seconds, is slightly longer than that of the parallel, 2·53 seconds, and if this difference be real, it may be traceable to the position of the flue causing the shaft to oscillate more easily in the transversal direction, but the evidence is inconclusive.

The diagram, Fig. 8, shows a succession of small and large vibrations at intervals of about 10 seconds or 12 seconds, the maximum motion never being continuous for any considerable length of time. In this respect the column behaved as a huge anemometer, to which it may be compared, and the duration of alternately large and small groups of vibrations may be regarded as indicating a comparatively rhythmical succession of periods of violent winds alternating with the times of approximated cessation. The motion recorded at the beginning of each group of vibrations probably measures the direct impulsive force of the wind, the increase in range after a few vibrations may be traceable to change of momentum or some more complicated motion due to eddies. This is the more probable as the extent of vibration in the



PLAN OF THE CHIMNEY. I-TOP. II-BASE.

initial impulse at the times of high wind increase roughly as the square of the wind's velocity. The paucity of observations does not permit any accurate comparison, but the conclusion is supported by the following figures:—

December 26, wind velocity 35 m. per sec.	(velocity-ratio)²	2.1
December 22, wind velocity 24 m. per sec.		
December 26, initial motion 46 m.m.	(amplitude ratio)	1.7
December 22, initial motion 29 m.m.		

Professor Omori has carried out similar observations on two other chimneys, at Skegawa and Tokio, each having a height of 100 ft. The general dimensions are as follows:—

—	External Diameter		Internal Diameter		Wall Thickness	
	Skegawa	Tokyo	Skegawa	Tokyo	Skegawa	Tokyo
	ft. in.	ft. in.	ft. in.	ft. in.	in.	in.
Base	5 7	7 9	4 7	5 6	9	9
Top	4 0	7 1	3 1	5 6	6	5

The ratio of external diameter to height in the three cases is:—

Skegawa	1:17·5
Tokyo	1:12·9
Saganoseki	1:12·9

The instruments used on the two smaller chimneys were the same as on the higher, and the general arrangements nearly identical. Unfortunately, in both cases, the weather was too calm to permit of any decisive conclusions. At Tokio the wind had a velocity of only 5 m. to 6 m. per second, and the oscillations were very small. The vibration period was 0·85 second and the maximum motion 0·2 mm. At Skegawa the maximum velocity did not exceed 14·3 m./sec. and the mean was only 9·6 m./sec. As might be expected from the quoted dimensions, this latter column proved itself very shaky and, as a matter of fact, could be thrown into vibrations of considerable amplitude by the exertions of a man mounted on the top. With a wind velocity of less than 10 m./sec. the double amplitude amounted to nearly 1 mm., a considerably greater arc than in the case of the 500-ft. chimney. The interest of the measures consists mainly in comparing the effect of artificial shaking with that due to wind action. The former may have been increased by "resonance." The length of the arc through which the column moved, and the period of vibration were sensibly the same in the two directions at right angles to each other, so that it will be sufficient to quote the results derived from the vibrations transverse to the flue.

Date, 1917.	Wind Force and Direction.	Effect of Wind.		Artificial Shaking.	
		Double Amplitude.	Period	Double Amplitude.	Period
Jan.	m./sec.	mm.	sec.	mm.	sec.
30, 3–3.30 p.m.	N.W.7·6–14·3	0·95	0·81	4·3	0·84
31, 10½–11½ a.m.	S.S.E. 5·8–10·0	0·70	0·81	5·0	0·81
31, 11½–12 a.m.	S.S.E. 5·8–10·0	0·90	0·82	8·4	0·82

The alternate growth and decay of the vibrations observed at Saganoseki was also remarked in the case of the smaller shaft.

The main conclusion reached is that wind pressure on a tall chimney can entail consequences as disastrous as those due to seismic motions, even in countries where such occurrences are frequent and severe. The observed motion of the Saganoseki chimney indicated a maximum acceleration of 565 mm./sec.², whereas on the occasion of the destructive Tokio earthquake of June 20, 1894, the intensity was 444 mm./sec.². Should the wind velocity reach 50m./sec. the vibration would acquire an acceleration of more than 1,000 mm./sec.². Only very near the epicentre of an earthquake is such an intensity to be anticipated. Again, a reinforced concrete chimney of less than 200 ft. in height must be regarded as a "short column," and in such structures it is desirable to reduce the height of the centre of gravity as much as possible. On the other hand, the 550-ft. Saganoseki chimney, and still more that of the 1,000-ft. chimney already projected, must be regarded as "tall columns," that are seismically weakest, not at the base, but at about two-thirds of the height. In the usual chimney construction the centre of gravity of the whole structure is situated at about one-third of the height, while that of the upper third portion alone, is nearly at the middle of its height, causing the shaft to be comparatively weak near the top. Professor Omori recommends such a distribution of the material, that the centre of gravity should be at one-fourth the height of the whole structure, as well as for the upper portion alone. In such a case the chimney would present uniform strength against an earthquake shock. But if the centre of gravity of the upper third part be about the middle of this section, the effect would be to weaken the shaft at the place where the seismic motion would be most effective.

That Japan should contemplate the erection of such lofty hollow columns on her earthquake-shaken rocks is a proof of the effectiveness of the study of the problem of constructional stability under adverse conditions, and furnishes conclusive evidence of the degree of reliance that can be placed on scientific deductions.

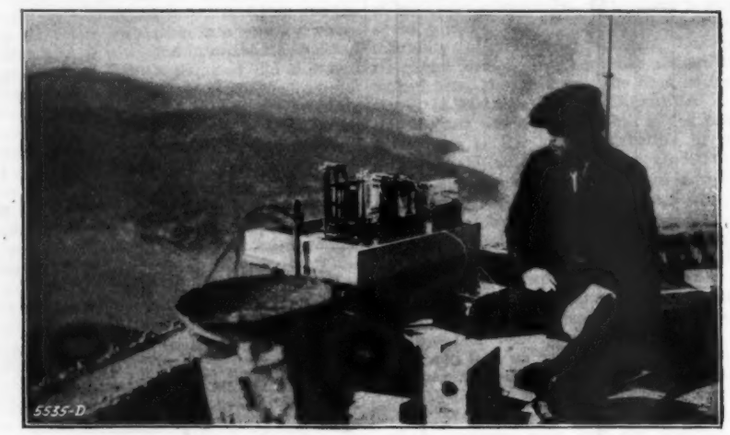


FIG. 6. TAKING SEISMOGRAPH READINGS AT TOP OF CHIMNEY.

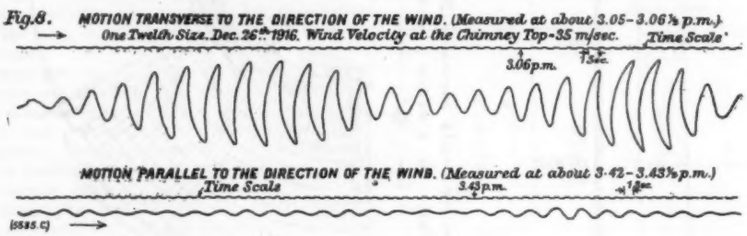


Fig.8. MOTION TRANSVERSE TO THE DIRECTION OF THE WIND. (Measured at about 3.05–3.06½ p.m.)
One Twelfth Size. Dec. 26th 1916. Wind Velocity at the Chimney Top-35 m/sec. Time Scale
3.06 p.m.
MOTION PARALLEL TO THE DIRECTION OF THE WIND. (Measured at about 3·42–3.43½ p.m.)
Time Scale
3.43 p.m.
(5535.C)

THE IRON AND STEEL INSTITUTE.

(*Concluded from page* 324.)

A FEW NOTES ON BOSH TUYERES.

ON the members re-assembling on Friday morning, the 13th inst., Sir Robert Hadfield, Bart., occupying the chair, the first paper taken was one on "A Few Notes on Bosh Tuyeres," by Mr. J. Hollings (Brymbo) who read it in abstract. Bosh tuyeres were not, he said, included as an integral portion of blast furnace design anywhere much before 1907. They seemed to have been originally used to meet emergencies only. They were rarely met with in the United States. If it were possible to obtain absolutely ideal physical, chemical and mechanical conditions in everyday blast furnace practice, they would probably be neither necessary nor desirable. The circumstances which led to their adoption at Brymbo were several years' bitter experience leading to the conclusion that as far as conditions there were concerned, the absolutely regular descent of the burden was of greater importance than the absolute regularity of any one other factor in furnace practice. We print the paper in full on page 356 of the present issue.

Mr. J. E. Fletcher, in opening the discussion, said that many blast furnace men had been considering the advantage or otherwise of using bosh tuyeres and Mr. Hollings's paper had thrown much light upon the results that could be obtained with them. Many factors came into play in regard to the desirabilty of using bosh tuyeres and in regard also

to their position, and American blast furnace practice would tend to show that there were yet many difficulties to overcome in connection therewith. The regularity in the charging, the slag question, the question as to where the slag began to form, and whether bosh tuyeres enabled the slag problem to be dealt with correctly, were some of the considerations which had to be taken into account. There was also the question of the stream paths from the tuyeres to the top of the furnace, and whether bosh tuyeres enabled the paths to be more correctly established.

Professor Turner, who spoke next, said that the meeting was indebted to Mr. Hollings for bringing the subject forward. The practice of introducing bosh tuyeres was gradually growing, but the literature on the subject was scanty, and the author's contribution was therefore a valuable one. The question, however, remained as to how far bosh tuyeres were of advantage in general practice. He knew of no theoretical advantage if the blast furnace were working regularly without bosh tuyeres and if the slag was going on well. As the slag became "sticky" it would lead to irregularity in the working of the blast furnace. Where there was a high melting slag to deal with it was of advantage to have a supply of air at a higher level and under control. Bosh tuyeres were intended rather to overcome a difficulty than otherwise, and the increase in coke consumption referred to by the author was exactly what the members would have anticipated.

Mr. E. E. Wood, who followed, remarked that the author had not pointed out the use of both tuyeres as an ideal, but as a very great assistance in keeping up the output of a blast furnace. He had an increased output following an increased burden and, of course, an increase in fuel consumption. The ore available was becoming leaner and leaner every year, and bosh tuyeres would assist in keeping the output to a normal figure.

Sir Robert Hadfield here asked the author for an idea of the ore he used, and said he had seen lately a quantity of highly phosphoric, very impure ore, at Banbury. Could the author work with ore of that nature.

Mr. Hollings, in the course of a brief reply, said that the burden was made up of 60 per cent. to 75 per cent. of the ore Sir Robert had referred to. The Briey and Longwy ore was of a somewhat similar class. There was an increase in the use of bosh tuyeres on both sides of the furnace; they prevented accumulations from forming in the bosh such accumulations interfering with the distribution of the gases more than any other factors.

On the motion of the chairman, the author was awarded a hearty vote of thanks for his paper.

The Cooling of Steel in Ingot and other Forms.

The next paper taken was the one "On the Cooling of Steel in Ingot and other Forms," by Mr. J. E. Fletcher, who read it in abstract. This paper, of which we commence the publication in full on page 342 of our present issue, deals with the subject very exhaustively. It states as an indisputable fact that molten steel, no matter how carefully made, contains a very considerable volume of gas in suspension. Cases have been known to the author where cast blocks of mild steel over a ton in weight (thick short slabs of rectangular section cast on the flat) have cooled without any trace of pipe, have proved solid and clean, and have shown less than half the normal coefficient of contraction. The steel had become nearly frozen in the ladle and was only just "live" enough to fill the mould without rising into the feeder-head. Apparently, during the prolonged stay in the ladle, occluded gases had escaped. The author investigated the influence of occluded gases by means of ingots and other forms made of flue cinder from puddling or pile reheating furnaces. The paper showed sections of these latter; one with wide bottom downwards, in which a smooth cavity was at top, there being primary crystals on the outside and secondary crystals in the centre; one with small bottom downwards, in the centre of which was a rough cavity, the primary and secondary crystals being located as in the former case. The effect of variable speed of cooling in the moulds was entered into largely, as also was the influence of cooling on the crystalline structure.

Dr. J. S. Unger, who opened the discussion, said that in making a study of blowholes in ingots by casting various materials into tin moulds, no very serviceable indication was obtained as to what obtained when casting steel into moulds at steel-works. His own experience in trying to investigate by casting an ingot of lead was not very satisfactory; lead contracted more than steel. He had tried also zinc, and zinc was better; its comparatively low melting temperature made it very suitable for laboratory investigations. In every case, however, the walls of the mould had always to be kept to proportions approximating those of actual service. If when casting a material in sand it was hoped to have results similar to those which obtained when casting in a metal mould there were bound to be disappointments. In steel practice the weight of the cast-iron mould should be approximately equal to the weight of the ingot, and in all laboratory investigations an endeavour should be made to duplicate at least that condition. The speed of pouring, the size of the nozzles, among other conditions, had also their importance.

Mr. E. H. Saniter said he had only had time to read a part of the paper, which was a voluminous one, but the part he had read covered the author's statement with regard to the action of gases in reference to shrinkage; he could not follow the author's theories as to that action. In properly made steel there was no free gas, and the author, he thought, had attributed too much to gas.

Mr. Cosmo Johns, who followed, found the paper so extensive that time was required to study it. He, personally, had given up long ago any idea of studying the behaviour of steel by observing what took place in pouring wax; it was interesting to note, in this connection, that the author had worked on slag ingots. He agreed with Mr. Saniter in regard to the gases and did not consider that in steel the gases affected the problem so seriously as the author thought. He would, however, contribute to the discussion by correspondence.

Dr. C. H. Desch found the paper a very interesting one. He had been fascinated at first by Mr. Brearley's experiments with wax, but he had arrived at the conclusion that they did not give conclusive results with reference to steel. He, also, could not agree with the author upon the influence of gas in steel. Convection currents, he pointed out, came in, and they were sufficient to determine the condition of growth of the crystals; they accounted for the peculiar flow condition referred to in the paper.

Dr. W. H. Hatfield wished to call special attention to Mr. Brearley's book on steel in which he dealt in detail with sound steel ingots; this was a most valuable work.

Dr. Rosenhain said one point had struck him in Dr. Desch's remarks, and that was the influence of the escaping gases upon the crystal growth; their influence was somewhat exaggerated in Dr. Desch's view. When a molten substance cooled down crystal nuclei were formed, and the number of nuclei was calculable. Tamann had illustrated that point. Dr. Rosenhain showed by a sketch on the blackboard the direction in which the nuclei tended to grow and how the growth took place. He did not think that the flow of gas determined the growth of crystals.

Dr. Stead and Professor Arnold also showed by sketches how, in their opinion, the crystals formed and started growing.

Mr. W. Lester congratulated the author for having put forward the results of his investigations which, he believed, had been carried out in the right direction. There was more in the freezing system of steel than had yet been accepted, and in this respect the author had applied points of a scientific nature to the means of obtaining sound ingots. He (the speaker) had always found that a bad teemer could spoil a good steel; in other words, it had too frequently been forgotten that proper teeming was an essential condition for the obtaining of sound steel.

Mr. H. H. Ashdown said that he had been much interested in the study of big ingots, and for the past four years in particular he had been carrying out some very close investigations. About four years ago he had a number of experimental ingots, made in the exact proportion of 100-ton ingots, cast under varying conditions, and the isothermal lines in regard to zinc followed absolutely the isothermal lines of cooling steel. He simply mentioned that because, as the secretary knew, he had had a paper under preparation for some time, but had not been able yet to complete it, and he did not wish the members to think at a later date that he was taking any undue advantage of what had been put forward by Dr. Unger at that morning's meeting. He had, as a matter of fact, in the study of big ingots, been watching the cooling effect of the bottom plate and the slower freezing of the metal in the top of the ingot due to the feeding head. The isothermal lines of ingots were generally shown in relation to small ingots and, owing to recent publications, specifications had lately been drafted calling for ingots to be made with their big end up. For ingots up to a certain size that was possibly correct, but when it came to large masses other problems were introduced which required careful thought. He was referring to ingots of from 10 tons to 100 tons in which the chilling effect of the bottom plate in addition to the chilling effect of the ingot mould had to be taken into consideration. When hollow forgings were being made the centre of the ingot was removed so that if by casting with the small end up the segregate extended a little lower down the centre of the ingot that was of no consequence. The upper portion of the ingot was better, as a good feeding head would ensure soundness and the chilling effect of the mould on the smaller upper section would force the segregate nearer the centre.

In the reverse type with the large liquid mass at the top, the segregate extended much further into the body of the ingot. The author had shown the effect of chilling according to the thickness of the wall of the mould. The dendritic structure would develop as long as there was a liquid mass for those dendrites to grow into, but by an intensified cooling it was strange that the whole of the dendritic structure was broken up, and that one obtained almost entirely throughout the mass equiaxial crystals. Here Dr. W. H. Hatfield asked the speaker whether it was advisable to cast with the large end downwards. Mr. Ashdown replied in the affirmative, saying that it offered very many advantages for big ingots. (Dr. Hatfield and Mr. Cosmo Johns stated this was contrary to their experience.) If one worked with the ingot mould inverted, added Mr. Ashdown, the segregate came almost to the outside of the ingot, and it also formed in a considerable portion of the usuable part of the ingot. In addition it offered many other advantages, such as stripping and so on; he made reference to his contribution to the discussion on Brearley's paper on Ingots. In the case of intense cooling, if a quick cooling action took place at the bottom, there was a very big risk of the ingot cracking transversely. Another point was that it did not matter how pure the steel might be to start with, if quick pouring took place it was possible to get the whole of the mass of steel segregated. He had seen ingots 100 tons in weight, made from the best Swedish or hematite iron, absolutely full of ghosts.

Sir Robert Hadfield said that the time had now come when it was necessary to save steel as much as possible. Several papers had been read of late on the subject. He (the speaker) had put forward the suggestion that, for investigation purposes, when the ingot cooled down copper should be poured in at the top, because by reason of its colour copper could easily be distinguished in the steel and the tendency of copper was to deposit in the unsound portion of the steel. The use of wax was a pretty experiment, the wax models shown at the Scientific Exhibition were very interesting, but they did not reveal what was going on in steel whilst this was cooling down in the ingot. The Allies were now making an enormous quantity of steel annually, and if only a fraction of that quantity could be saved the total saving would be very important. He recommended that a theoretical and practical committee—to be an Allies committee—should be formed, to study that point. The question of

fuel saving also came in, and that was a most important and vital one, for large quantities of steel were melted down over and over again. That could be avoided. In regard to the saving of fuel for the Allies a committee could give most valuable information. Sporadic discussions in reference to these matters were not sufficient, they lacked co-ordination. As early as five years ago he (the speaker) obtained 90 tons of billets from 100 tons of ingots; a similar result could be obtained by all steelmakers. One of his ingots had been cut open by Dr. Burgess, of Washington, and he had found no pipe and no blowholes after discarding 10 per cent. It was necessary to better train our labour on steel-making.

Professor W. A. Bone here stated that the present fuel situation prompted him to make a few remarks. He thought we should very soon have to face the industrial rationing of fuel, and the iron and steel industry would not escape that necessity. There were many ways in which fuel could be rationed, and it was very desirable that whatever were the steps taken they should be the right ones and those which the industry felt were on rational lines. He suggested that the Institute should take into account the seriousness of the situation and should appoint a committee to consider and to represent the views of the industry upon the economies which could immediately be effected, the committee then to make recommendations to the Coal Controller.

In the course of a brief reply to the discussion, Mr. Fletcher said he had been greatly interested in the views on crystalline structure and growth put forward by Dr. Desch, Dr. Rosenhain, Dr. Stead and other speakers; his mind was open to their remarks, but he did not feel perfectly certain that the gas flow came in to influence the crystalline structure. The point, so far, was not proved or disproved. Gas inclusions did not of a necessity mean bad steel. On examining sections of ingots—and he had shown some in his paper—it would be seen that the axes of the dendrites always tended to rise towards the top. As far as the gas problem was concerned, he had perhaps brought this forward in an exaggerated form. They had to give foremen their instructions and mentioned to them the great importance of the gas flow; if the men began to consider that the gas flow and contraction could not be divorced they gave better attention to their work, and the result was better castings. He showed on the blackboard an ingot shape, having the large end up, a rounded bottom and the taper he suggested, at various parts over its height.

Here followed an informal discussion on the proposal for the formation of the committee referred to above; the members were unanimously in favour of its formation, and it was ultimately decided that the existing Committee No. 3 on Steel would be the suitable one to deal with the problem and to receive any Government grant available.

On the motion of the chairman, Mr. Fletcher received the thanks of the meeting for his valuable contribution to the proceedings of the Institute.

The Principles of Open-Hearth Furnace Design.

The paper by Mr. C. H. F. Bagley, on the "Principles of Open-Hearth Furnace Design," was next taken. It was read in abstract by the author, and we shall publish it in a future issue. It gives information on furnace details, figures of gas combustion, of air supply and sections of furnaces at various points. A special chapter deals with the application to open-hearth furnaces of boilers for the utilisation of waste heat.

Professor Arnold, who opened the discussion, said he agreed with the author's opening statement to the effect that in order to melt steel at all it was hardly possible to attain too high a flame temperature, provided the flame was under control and not allowed to impinge upon the brickwork, and so forth, and asked what was the calorific intensity in the author's open-hearth furnace. At the Sheffield University they found this to be 1,700 deg. to 1,750 deg. and the tapping temperature 1,590 deg. to 1,620 deg. These temperatures were very much the same in large and in small furnaces. But, Professor Arnold remarked, the melting-point of silica bricks given in text-books was lower than these figures. He also asked whether the temperatures at the inlet valve and after regeneration quoted by the author, together with the temperature of the waste products at the port face, were guesses or actual measurements.

Mr. E. H. Saniter, who followed, said he had read the paper with great interest; it would also have the careful consideration of No. 3 Committee, who would welcome all papers and discussions on the subject. The author had quoted an example of very interesting German practice in which an excellent output had been obtained on the scrap and pig-iron process; Mr. Saniter asked whether the author could supply a design of that furnace or give its dimensions. The author had further said that the furnaces on the Continent and in the United States were rated at a lower capacity than in this country. He (the speaker) believed they were rated at a lower capacity, but not to so low a capacity as suggested by the difference in output. The author had stated that he half filled the slag pockets with perished dolomite and Mr. Saniter asked what was his object in doing so.

Professor W. A. Bone found the subject dealt with an important one. One of the first things in furnace design should be a proper appreciation of what takes place in combustion and of what heating depends upon. Designers occasionally did not sufficiently follow the science of flame, and this led to misconceptions. He (the speaker) did not know what was meant by the term "theoretical flame temperature"; this was not correct, there was no such thing, and the term should be banished. The flame temperature under certain conditions he could understand. One did not depend upon the flame in the furnace at all, but upon the radiating effect in the furnace. His book on the subject dealt with it exhaustively. In the furnace, the heat was given from radiation by flame; the temperature of the flame was important only so far as it effected radiation. Steam in the checker chambers did not dissociate into hydrogen and free oxygen, as the author had stated; higher temperatures were necessary for that, and the steam reacted according to the formula $CO + OH_2 \lesseqgtr CO_2 + H_2$. He was sorry the author contemplated using 25 per cent. excess of air to insure complete combustion; a furnace properly designed should not require more than 10 per cent. excess of air to completely burn the gas in the furnace. He hoped the author would be able to reduce his figure.

Mr. H. M. Ridge said that in the steel furnace there were two essential duties, the heating of the steel and the supply of a certain amount of air for oxidation. Could the author enlarge upon the latter point, in regard to the 25 per cent. he mentioned as excess of air? Observations in a steel furnace were very difficult to carry out; gas samples were taken, but it was practically impossible to ascertain what took place in the steel bath. In dealing with other metals, he had found it essential that the air and gas passed should be in a violent state of commotion and be deflected downwards as much as possible. It was only comparatively small strata of gas over the molten bath which acted, the rest did not supply oxygen, and did not contribute much by way of heating. A few inches at the bottom of the gases only were active and he found that for every inch the arch was brought down the results were improved appreciably. An ideal fire-brick material for building the arch was still to be found, and until then it had to be given an excessive rise. Lowering the arch was an advantage, and it decreased the amount of gas necessary for producing the required effect.

Mr. Cosmo Johns found the paper a very useful one. He confirmed what Professor Bone had stated. A high percentage of carbon monoxide was practically very much better than a high percentage of hydrogen, since the latter constituent also affected the roof of the furnace. The average gas composition Mr. Cosmo Johns gave was $CO_2 = 3{\cdot}5$; $CO = 29{\cdot}9$; $H = 10{\cdot}5$. This could easily be produced. In the gas producer the air and steam inlets were under separate control. The area of the gas ports should be as small as possible. He (the speaker) referred to his former publications on the subject dealt with. He showed in a sketch on the blackboard that the highest temperature was at the flame, 1,850 deg. just over the bath; the next highest temperature was at the surface of the bath. The roof was always the coolest part; it carried the flame directly down over the surface of the bath. He would like the author to state the limits for the composition of the waste gases leaving the furnace.

Mr. Bagley, in the course of a short reply said with reference to Professor Arnold's questions, that his figures were assumed; the paper dealt with principles and the figures would vary when working under different conditions. It was customary to put perished dolomite in all the furnaces with which he had been connected, the slag ran off easier. He agreed that the 25 per cent. air excess was a high figure, but in actual practice it would be found that the men did not adjust the valves to a nicety with a view to theoretical combustion.

The author received a hearty vote of thanks for his communication.

The Utilisation of Waste Heat from Open-Hearth Furnaces for the Generation of Steam.

The last paper taken at the meeting was the one dealing with "The Utilisation of Waste Heat from Open-Hearth Furnaces for the Generation of Steam," by Mr. T. B. Mackenzie, who read it in abstract. The average weight of steam obtained per ton of ingots was 987·5 lb., but under more favourable conditions there seemed reason to believe that at least 1,200 lb. of steam would be obtained.

Dr. J. S. Unger, who opened the discussion, said that a reconsideration of the question of utilising waste seemed to be necessary; it was a growing question. In America, steel makers did not as a rule recover the waste heat from their open-hearth furnaces. In this connection, it should not be forgotten that the use of powdered coal was greatly increasing in the United States steel works, and the temperatures of the gases leaving the furnace were much higher and the draught at the chimney very much greater than was the case with gas. In these conditions, facilities would have to be provided for the easy and rapid cleaning out of the boiler tubes. In American open-hearth practice, Dr. Unger added, the frames, doors and other parts of the furnace were being constantly cooled by water circulation, and he believed the open-hearth furnace of the future was going to be a steel box, adequately water-jacketted all round on the outside and lined throughout in the inside with brickwork.

Mr. Cawl, who followed, stated that many manufacturers were not given sufficient data upon which to provide a suitable boiler plant. The author, he added, had a very interesting series of temperature records of his installation; he would like to know whether he had also similar records of the CO_2 in the gases taken at various points. He (the speaker) mentioned an installation of his in which temperature by CO_2 readings were taken every quarter of an hour.

Mr. E. H. Saniter stated that the question of fitting boilers to open-hearth furnaces had been in consideration for many years and a number of papers had been read on the subject. Whether the installation was economical or not depended upon the temperature of the waste gases leaving the furnace. In the paper, the temperature of the waste gases varied considerably, and when it was under 500 degrees there was little gain to be expected. The economy might perhaps reach 7½d. per ton on pre-war prices; could the author say how much capital would have to be expended to obtain that result? Nothing was said about labour; the boiler tubes would have to be kept absolutely clean and would have to be attended to several times a day. What, therefore, would be the capital cost, the cost of upkeep and of labour to put against the possible saving?

The author stated that he would reply in writing. He was awarded the thanks of the meeting for his contribution.

The remaining papers on the list were taken as read, and the usual vote of thanks to the Institute of Civil Engineers for the loan of their hall and to the chairman terminated the proceedings.

STEAM TURBINES FOR NATURAL STEAM POWER PLANT AT LARDERELLO, ITALY.

IN our issues of May 10 and May 24 last, pages 507 and 567, we published an exceedingly interesting account, by Signor Ugo Funaioli, of the natural steam power plant installed at Larderello, in the Province of Tuscany, Italy, and we now supplement these articles by a description of the steam turbine plant by which the supply of natural steam is utilised. In the region named, as in certain other quarters of the globe, there is a constant emission of steam and hot water from crevices and fissures in the ground. Elsewhere such phenomena have been looked upon merely as natural curiosities, but the fact that at Larderello the hot water was found to be highly charged with boric acid, led, just a century since, to the commercial exploitation here of these freaks of nature, the boric acid being extracted and sold.

In order to increase the output, bore holes were sunk to supplement the natural flow. Some of these bore holes are as much as 16 in. in diameter, and range in depth from 200 ft. to 500 ft. The supply was thus largely augmented, and on closing in the top of some of the bore holes it was found that the steam pressure reached about 45 lb. (gauge). This observation led to the idea of utilising the steam for power production. The project appeared the more promising in that a continuous and ample supply seemed to be assured, since it was found that the large increase which had been made in the number of bore holes sunk had in no way diminished the flow from previously-existing vents. A small reciprocating engine was therefore put to work in 1897, whilst a larger engine was installed in 1905. Both worked very satisfactorily, and it was evident that sufficient steam was available to operate plant of a considerable capacity. The available pressure was, however low, since, although with no flow the pressure reached 45 lb. (gauge), it fell as the delivery increased, and it was found that not more than 30 lb. (gauge) should be reckoned on as the effective pressure of supply. At the same time, as a bore hole is in the nature of things, very adequately lagged, the temperature of this steam, as delivered, was much above the saturation temperature, being 180 deg. C., which, if the steam were saturated, would correspond to a pressure of about 145 lb. absolute.

The condition of a supply of steam at low pressure and with a considerable superheat, is one which is better adapted to the steam turbine than to the reciprocator, but, on the other hand, the natural steam at Larderello is highly charged with CO_2 and other gases which would make it difficult to secure the high vacuum, lacking which the advantages of the turbine are materially discounted. Hence, when the first turbine, a 250-kw. unit, was installed in 1912, it was decided to use the natural steam merely as a heating agent, and by its aid to evaporate pure steam at a lower pressure, and to use this pure steam in the turbine. This plan proved quite satisfactory, and it was resolved to adhere to it, when installing the three 2,500-kw. turbines, which were put into service in 1916.

The evaporators used to supply the pure steam were described in our issue of May 24 last, page 567. They each consist of a vertical steel drum, the headers of which are tube plates, into which are expanded 300 aluminium tubes. These tubes are 7 metres long and 30 mm. in diameter. They were made of aluminium in order to resist the action of the sulphuric acid, of which a certain proportion is found in the natural steam. This natural steam flows outside the tubes, and the water to be evaporated through them. The steam generated passes through a superheater before it enters the main steam range. This superheater is heated by the natural steam on its way to the evaporator. The pressure at which the pure steam is generated is about 15-lb. gauge, but the turbines are designed to give their rated load, with a gauge pressure at the turbine of 2½ lb. per square inch.

The general layout of the turbine room at the Larderello power station is represented in Figs. 1 to 4, Plate XXIX. The small 250-kw. unit erected in 1912 can be seen to the left in Figs. 1 and 3, whilst to the right are shown the three 2,500-kw. turbines which have been constructed and erected by Messrs. Franco Tosi, of Legnano, Italy. These turbines run at 3,000 r.p.m., and are coupled to Brown, Boveri generators, supplying three-phase current at 4,000 volts and at 50 periods per second. A view showing the three sets in place is reproduced in Fig. 12, page 346. The turbines are of the standard exhaust steam type, with reaction blading. As will be seen from Fig. 13, page 346, which shows the motor suspended over the lower half of the casing, the turbine is built on the double-flow principle, steam being admitted at mid-length, and flowing both ways to the exhaust ports at the ends. There are thus two exhaust flanges which bolt on to corresponding branches on the condenser, as is indicated in Figs. 2 and 4, Plate XXIX. The blading is divided into seven groups, of which five have brass blades, whilst the two remaining low-pressure groups have blades of 5 per cent. nickel steel.

The glands have carbon packings, which are

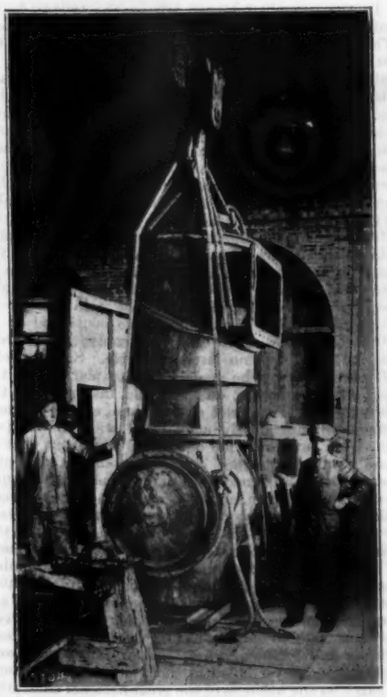


FIG. 14. STOP-VALVE AND MAIN GOVERNOR-VALVE.

illustrated in Figs. 9 to 11, Plate XXIX. It will be seen that the carbon rings do not bear directly on the shaft, but on to a thin steel sleeve, which stands clear of the shaft. The possibility of distortion is thus minimised, since the steam in the annulus between shaft and sleeve keeps the latter at a nearly uniform temperature. The carbon rings are in four sections, and, as shown in Fig. 10, are held together by helical springs embracing them. The rings are, moreover, supported from below by coach springs, as shown, so that their weight is not carried by the sleeve. By these precautions, wear is reduced to a minimum, and permanent tightness ensured. The section through the gland reproduced in Fig. 11, passes through the annulus by which live packing steam is admitted to the gland. Sufficient pressure is maintained in this space to prevent any possibility of air leakage into the turbine.

With all exhaust-steam turbines, the design of the valves is a crucial question. The volume of steam to be passed is enormous, and a loss of pressure at the valves, which might be insignificant in the case of a high-pressure turbine, will materially reduce the output of an exhaust-steam turbine. The general valve arrangement adopted by Messrs. Franco Tosi is illustrated in Figs. 6 to 8, Plate XXIX, whilst Fig. 5 shows a section through the main valve. A good idea of the proportions of this valve will be obtained on referring to Fig. 14, annexed, which is reproduced from a photograph.

As shown in Fig. 5, the stop-valve V_0 and the governor valve V_1, are combined in the one casing. Both are of the double-beat type and are designed to pass 90,000 lb. of steam per hour at 2½-lb. gauge pressure. The steam enters the valve casing from below, the admission pipe being 700 mm. in internal diameter. Provision is made for the expansion of this pipe without straining the valve, by employing a gland as indicated. The stop valve V_0 is opened downwards by admitting oil under the piston S, which is coupled by appropriate linkwork to the lever L. The amount of the opening is controlled by the handwheel N, and by this handwheel the valve can be firmly locked in the closed position when desired. On destroying the pressure of the oil below the piston S, this piston is forced down by the action of the spring M, and closes the stop valve.

The governor valve opens upwards, and its position is controlled by regulating the supply and leak off of oil below the spring-loaded piston, S.M. The valves which control this oil supply are of the piston type, and as shown, are very compactly and neatly arranged below and concentric with the piston S.M. In their turn, these valves are controlled by the governor in the usual way. The linkage by which this control is effected is illustrated in Figs. 6 to 8. from which also it will be seen that in addition to the main valve shown below in Fig. 7, and to the right in Fig. 8, there is also an overload valve which is shown on top of the turbine in Figs. 6 and 8. This overload valve, which is also oil operated under control of the governor, short circuits part of the blading, and thus increases the weight of steam which passes through the turbine, and thereby increases the output.

A speeding gear, electrically operated from the switchboard, permits of the rate of revolution being varied through a small percentage as the conditions may demand. The motor which operates this control can be seen to the left of the turbine in Figs. 6 and 7, and to the right in Fig. 8.

Each turbine has its condenser arranged immediately below it, as indicated in Figs. 1 and 4, Plate XXIX. Each condenser has a cooling surface of 11,300 sq. ft. The air pump is of the water-ejector type, and the condensate is handled by a centrifugal pump. The system was described in detail in our issue of April 26, 1912, page 559. With the byepass in operation, the turbines develope about 3,000 k.w., and the weight of steam passed amounts to about 90,000 lb. per hour. The circulating water required is 9,300 gals. per minute, and as this is derived from cooling towers, its temperature is never really low. The efficient working of the turbines is thus bound up with the efficiency of the air extraction and the makers state that with the ejector air pump fitted, the results have been highly satisfactory. Altogether the installation is a most interesting one.

INDUSTRIAL NOTES.

THE following are some recent decisions given by the Committee on Production on cases which have been referred to them by the Ministry of Labour:—

Aircraft Workers: From August 10, 1918, an advance of 3*s.* 6*d.* per week is to be paid to skilled woodworkers, painters, polishers, dopers and upholsterers employed in aircraft establishments; that, is, any manufacturing establishment engaged wholly on the manufacture or repair of aeroplanes or seaplanes, or of components or parts thereof, and any workshop belonging to a composite establishment in which such work is exclusively carried on.

Shipbuilding Trade—Southampton: From the first pay after March 7, 1918, a further advance of 10 per cent. to be paid on gross earnings in the case of platers and angle-iron smiths, and 20 per cent. on current piece rates to caulkers engaged on merchant ships. From the first pay after May 1, 1918, the pre-war piecework prices for Admiralty work at Southampton to be advanced as follows: Riveters by 35 per cent. (plus, 2½ per cent. for holders-up); caulkers by 20 per cent.; platers and angle smiths by 10 per cent. A further advance of 20 per cent. over pre-war rates to be granted to lieu workers on merchant work and Admiralty work at Southampton from first pay in May and July 27, 1918, respectively.

The first of an important series of lectures arranged by the Industrial Reconstruction Council will be held

in the Saddlers' Hall, Cheapside, E.C. 2, on Wednesday, October 2. The chair will be taken at 4.30 by the Right Hon. G. N. Barnes, M.P., and an address on "Commerce and Industry after the War" will be given by the Right Hon. Sir Albert Stanley, M.P., President of the Board of Trade.

The first annual general meeting of the Industrial Reconstruction Council was held on Tuesday, the 17th inst., the chairman, Mr. Ernest J. P. Benn, C.B.E., presiding. In his *résumé* of the present year's work, Mr. Benn remarked on the extraordinary growth of public interest in the great problems of Industrial Reconstruction. After the war it was the first topic discussed in all quarters and by all classes. He ventured to hope that it was in no small measure due to the efforts of the Industrial Reconstruction Council that the principle underlying the Whitley Report was now so widely accepted, and that everywhere our industries were awakening to the need for closer organisation. The Industrial Reconstruction Council held fast to its watchword of Industrial Self-Government and by insisting on the only sane interpretation of that phrase was, he thought, doing useful work in counteracting the dangerous revolutionary influences that were abroad. Mr. Benn gave a brief summary of the year's activities in the way of meetings, lectures, conferences, and the publication and distribution of literature, and made a strong appeal to those present to secure fresh adherents to the cause, and thus further the possibilities of future development.

A conference on Trade Boards was held under the auspices of the Industrial Reconstruction Council last Tuesday, the 24th inst. The subject was introduced by Mr. J. J. Mallon, of the Anti-Sweating League.

On Friday, the 20th inst., Sir Albert Stanley, President of the Board of Trade, addressed at the Mansion House a meeting of metropolitan and other mayors, under the chairmanship of the Lord Mayor, to put before them the seriousness of the present coal situation. The coal shortage was at the present time 36,000,000 tons. We had to meet our own needs, those of our Allies, and also those of several neutral countries; our duty, therefore, was to save all the coal we could. The rationing of coal was on a liberal basis, and if it succeeded we could secure thereby a surplus of coal for other purposes of 8,000,000 tons. This, however, would not meet the deficit of 36,000,000 tons, and the difference had to be met somewhere, either by reducing our household supplies further, or by giving our Allies less, or, as an alternative, we should be unable to meet our debt of honour to the neutral countries who had given us their ships in exchange for coal. We had remaining in the mines about 150,000 miners less than we employed at the outbreak of war. Every member of the Miners' Executive had pledged himself to do all that lay in his power to encourage the men to increase their output. But if they asked the miners to make an extra effort, those who were using coal must also make some sacrifice. There were already under way 20,000 miners from the army. Sir Albert Stanley urged the mayors to give him their assistance; he felt convinced that when the people understood the situation and realised that sacrifices were in the national interest, then there would be the necessary co-operation to make a success of the rationing scheme and of coal-saving generally.

The statement is made that 400 experts have been appointed by the Coal Controller to consult with and advise steam-power users how to eliminate waste. As the result of an inquiry by the Coal Control Technical Department it is clear that tremendous wastage of coal is going on which could be prevented.

It will, however, take several years to recover the whole of this loss, even if a supreme effort is made by all the industrial firms, as it is impossible to instal more efficient plant while the war is on. Another cause of wastage of coal is the employment of unskilled stokers, and, unfortunately, there are to-day perhaps more men of this description than at any other time, as so many skilled stokers have joined the army.

There are 45,000 users of steam plant in Great Britain. Up to the present reports on 364 firms have been carefully scrutinised, and it is estimated that a saving of approximately 106,000 tons will result. This saving can be effected without any serious alteration to plant in the following directions:—

1. Obtaining greater efficiency in the combustion of fuel.
2. Education of stokers.
3. Utilising the heat in the gases to better advantage.
4. Using exhaust steam for heating feed water.
5. Adjusting engines more efficiently to use the steam generated.
6. Using the hot water from the condenser discharge for boiler feed purposes, instead of cold water.
7. Effective lagging of steam pipes.
8. Disconnecting steam pipes not in use, &c.

Mr. Gompers, President of the American Federation of Labour, has addressed the following message to the shipyard workers of this country:—

"This is a tremendous war thrust upon the allied countries; it is a war which no liberty-loving man or woman can fail to make the fullest sacrifices to win. Service and sacrifice are not confined to the men upon the firing line, but to all, including the men and women engaged in all industries.

"Two of the most essential industries during this critical period are coal and ships. The shipbuilders and miners have done splendidly, and yet superhuman efforts are essential to make the victory over autocracy and militarism complete.

"In the United States ships are being built and launched faster than at any time in the history of the world. A few days before I left America a 12-000-ton steel ship was launched in 24 working days from the time its keel was laid.

"America is giving and will continue to give its full man-power, and of its great wealth, to secure an early and triumphant conclusion of the war for freedom.

"I feel confident that the workers of Britain, including the shipyard workers, will continue to do their level best for the attainment of our common ends."

In the course of his speech at the twenty-fourth ordinary general meeting of Sir W. G. Armstrong, Whitworth and Co., Limited, held in Newcastle on the 18th inst., the chairman of the company, Mr. J. M. Falkner, said ". . . Our shareholders will naturally wish to hear how these problems in relation to capital and labour—problems which are attracting most attention at present—are being treated by this company. I can assure the shareholders that these questions are receiving careful and constant examination, and that we are thoroughly alive to the fact that the discussion of small causes of friction is often able to remove these causes before they are allowed to grow into more serious differences. I should like to have said more on this point, but I am warned that the moment is premature, and that it would be wise to await the issue of further inquiries before treating it more definitely. During the past two years our relations with our workpeople have continued to be satisfactory. We have had our controversies from time to time, but no lasting trouble. Some special reference may well be made from this platform to the good spirit which has, on the whole, distinguished the workmen of this district during these exacting times. Those who are closely acquainted with the subject will, I am sure, bear me out in the statement that in more than one rather critical instance the sound common sense and good spirit of our workmen did much to save the situation, and to demonstrate the deference paid in the labour world to the opinion of the Tyne. In our own works I gladly acknowledge the tact of the management which has contributed to the settlement of many passing difficulties. I am far from confining our commendation of our staff to this detail. I must not mention names, as it might be invidious, but I am sure that I may on behalf of the shareholders convey our gratitude to our managing directors, managers, officials and foremen, who, through weary days and nights, have never failed in their unremitting labours to carry on the business of the great national enterprise with which we are connected. . . ."

The strike of shipwrights on the Clyde involves the great majority of the men of this craft in the district. The strike arises out of a demand on the part of the men for a minimum wage of 5*l.* per week. This demand has been rejected by the employers; it has been disavowed by the executive of the Engineering and Shipbuilding Trades Federation; and the executive of the Shipwrights' Trade Union has dissociated itself from the strike, and has strongly urged the men to return to work, but without effect. At the time of going to Press the situation is uncertain, but the Government are expected to take drastic action.

A strike of railwaymen in South Wales has also broken out, and has spread beyond the district. The railwaymen generally accepted the recent offer of the Government of a 5s. bonus, and agreed to the formation of a committee to fix future wages in accordance with the cost of living. The railwaymen in South Wales are disappointed at the fact that the full demand for an increase of 10s. was not granted. They struck contrary to the advice of the trade union officials. Other districts became affected, but as the Government adopted strong measures there is every indication of the men returning to work.

BY-PRODUCT RECOVERY IN IRON AND STEEL WORKS: ERRATUM.—In our article under the above title, on page 206 *ante*, near the end of the third column, the coal consumption should read 250 per thousand, instead of per cent. In the installation referred to, the coal consumption in the gas generators is 250 lb. for every 1,000 lb. of steel produced in the open-hearth furnaces.

NOTE ON THE WARPING OF STEEL THROUGH REPEATED QUENCHING.*

By J. H. WHITELEY, Stockton.

DURING the course of the discussion of Dr. Carpenter's paper on "The Growth of Cast-Iron after repeated Heatings," Dr. Stead referred to the effect of repeated cooling in water on some large steel tongs which became red-hot each time they were used. He remarked as follows:† "The result of the continued heating and cooling was to cause a very material contraction in the

FIG. 1.

FIG. 2.

FIG. 3.

FIG. 1, STEEL ROUND; FIG. 2, DITTO, AFTER 200 QUENCHINGS; FIG. 3, DITTO, AFTER 800 QUENCHINGS. REPRODUCED TWO-FIFTHS ACTUAL SIZE.

length. The envelope contracted when being cooled, whilst the portions below were more plastic than the chilled outer layers. The effect was that the more plastic central portion was forced or 'jumped' down, causing contraction in length and bulging of the sides. There was probably no decrease in the actual volume, but only a change in the position of the steel. Incidentally it might be remarked that the result obtained suggested the somewhat startling hypothesis that if an oblong bar of soft steel were to be heated and cooled a sufficient

* Paper read before the Iron and Steel Institute on Friday, September 13, 1918.

† *Journal of the Iron and Steel Institute*, 1911, No. 1, page 235.

THE WARPING OF STEEL THROUGH REPEATED QUENCHING.

FIG. 4. SULPHUR PRINT FROM SPECIMEN IN FIG. 3; SLIGHTLY REDUCED.

FIG. 5. × 320.

FIG. 6. × 320.

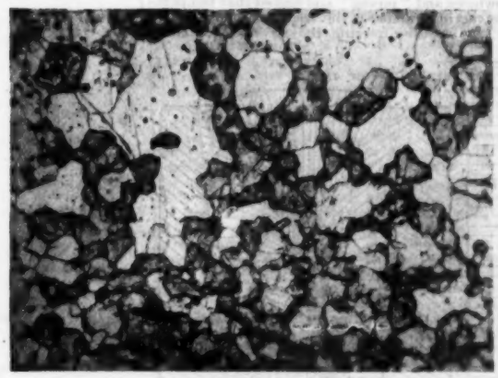


FIG. 7. × 140.

number of times under proper conditions, it would eventually assume a globular shape." An almost perfect instance of the effect here so well predicted has recently come under the author's notice, and it was thought that a short note on the subject might be of some interest.

In order to warm a small tank of water used for moulding purposes at the workshop of Robert Roger and Co., Stockton, a piece of iron, weighing several pounds, is heated over a coke blazing fire to a blood-red heat (700 deg. C. to 800 deg. C.). It is then gripped with a pair of tongs and moved about under the water until it is nearly cold. Some years ago a cylindrical piece of soft steel, similar in shape to that shown in Fig. 1, was cut from a round bar of about 3·5 in. diameter and used solely for this purpose. The analysis of the steel was as follows: Carbon, 0·05 per cent.; silicon, 0·01 per cent.; phosphorus, 0·08 per cent.; sulphur, 0·05 per cent.; manganese, 0·45 per cent.

About 200 heatings and quenchings were given during a year, and in the course of four years of this treatment the cylindrical piece had gradually become nearly spherical in shape, as shown in Fig. 3. An intermediate stage in the transformation is seen in Fig. 2, which is a photograph of a similar piece after it had been subject to about 200 quenchings.

Dr. Stead's remarks, quoted above, are clearly illustrated by these examples, the pressure on the hotter internal metal due to the more rapid contraction of the chilled outer layers having ultimately caused the piece to assume the globular shape shown in Fig. 3. The circular edges of the cylinder can still be seen, however, and it is probable that, if the metal had been somewhat harder in quality, these edges would have flaked off, as they were the parts most rapidly cooled in quenching.

Measurements taken indicated that, after 800 quenchings, the cylinder had contracted in length about 0·75 in. and had also increased in width by a corresponding amount. Each quenching must therefore have caused a maximum displacement of material in a lateral direction of about $\frac{1}{1333}$ of an inch. In this connection it may be remarked that the internal forces due to the tension of the skin may be resolved into two components, one acting parallel with the vertical axis, and so tending to shorten the cylinder, the other acting at right angles to the axis, and so tending to lengthen the cylinder. The direction and amount of movement in the piece which will take place during each quenching will depend upon the difference between the sum totals of the two components acting at various points in the material.

In order to obtain some idea of the way in which the metal had flowed, the ball (Fig. 3) was cut in two and the sulphur print shown in Fig. 4 was taken on the cut surface. The lateral expansion is here clearly seen, and it will be also noticed that just below the top and bottom surfaces the metal appears to have contracted, since the two heavy sulphide lines there bend inwards.

Sections of this sample were examined under the microscope, and several interesting features were observed. Two in particular, which are described below, seemed to have been brought about by the numerous quenchings to which the metal had been subjected. Some attention was given to the large indentations seen on the surface of the specimen in Fig. 3, but no evidence could be obtained to indicate whether this reticulated appearance of the surface was due to corrosion or to a creasing of the skin through contraction.

1. The shapes of many of the elongated particles of manganese sulphide present in the highly-segregated bands shown in Fig. 4 strongly suggested that these particles had been twisted and contorted by the repeated quenching. Several instances were observed in which the particle had been bent almost through a right angle without breaking. An example of this effect is seen in the upper part of Fig. 5. In other parts of the steel the shapes of the particles appeared to differ in no respect from the straight or slightly sinuous forms usually found in rolled sections. Exactly how the quenching had brought about the marked distortion of the particles in the segregated areas is not easy to say, but it would seem as though the rates of movement of adjacent parts of the bands had sometimes varied considerably. Further evidence of this is shown in Fig. 6. Here the composite particle of slag and sulphide has been sheared in two, and one-half has evidently moved across the other.

2. Cupric etching reagents showed the dark sulphide bands in Fig. 4 to be also rich in phosphorus, as indeed was to be expected. The ferrite grains in these areas were found to be much larger than those in other parts of the steel. The difference in grain-size is seen in Fig. 7, which is a photograph taken at the margin of one of the bands. Some segregated areas were undoubtedly richer in phosphorus than others, and it was noted that the largest grain-growth had occurred in the most highly phosphoric portions, the volumes of the grains throughout being from 10 to 100 times greater than those in other parts of the material.

This feature, like the previous one, could scarcely have been present in the steel as rolled.* It is far more probable that the large grains are due to growth following deformation, seeing that after each quenching the piece was reheated to a temperature (700 deg. to 800 deg. C.) suitable for this effect. Within the temperature range employed the small amount of carbon present would not diffuse into the phosphoric bands,† and the gradual grain-growth in these areas would not therefore be checked by the diffusion of carbon into them as would be the case in other parts of the steel.

The author is indebted to Mr. Robert Roger for kind permission to make use of the specimens here described and for information given concerning them.

* Dr. Stead states that, after forging, such phosphoric grains do not re-grow, as the metal cools, to the same extent as grains lower in phosphorus. *Journal of the Iron and Steel Institute*, 1915, No. I, page 162.

† *Journal of the Iron and Steel Institute*, 1915, No. I, p. 168.

COKE FORMATION.—Experiments by Georges Charpy and Marcel Godchot, described in the *Comptes Rendus* of August 26, 1918, show how necessary or desirable it is to study the favourable coking conditions for every coal. Having made some general experiments last year, they proceeded to study mixtures, taking in the first instance a coal from Brassac, containing only 11 per cent. of volatile matter, and a Durham coal with 24 per cent. of volatile constituents. Mixtures of the two coals in different proportions were coked at 700 deg. C., and the cokes obtained were submitted to crushing tests; mixtures containing 25 per cent., 44 per cent., 51 per cent. and 56 per cent. of the Durham coal gave cokes of strengths 24 kg., 45 kg., 80 kg. and *nil* kg. per square centimetre. Thus the strength of the coke increased to a maximum as more Durham coal was used, but dropped off suddenly when the percentage of Durham coal exceeded 51; alone the Durham coal gave a poor, friable coke, and the Brassac coal would not coke. The best average contents of volatile matter in this mixture was 19·6 per cent., and a mixture of Durham and Cardiff coals also gave its maximum strength (70 kg. per square centimetre) for about 19 per cent. of volatile matter. Tar and pitch were likewise used with good results to improve the coking properties of meagre coal. Another series of experiments was undertaken to ascertain whether low temperature distillation at 450 deg. C., followed by coking at 700 deg. C., would give good results. Again a curve with a decided maximum was obtained, demonstrating that in such operations the suitable temperature and duration of the heating period should be predetermined by careful experiments. When the distillation (at 450 deg. C.) was conducted for 0, 30, 90, 105, 120, 150, and 160 minutes, the percentages of volatile constituents remaining in the coal amounted to 28, 23·5, 21·6, 20, 18, 16·6 and 14·8; the subsequent coking gave a very friable product in the first three cases; in the other four cases the strength of the coke was 41, 97 and 25—very small. Thus to obtain a good coke this Durham coal should not be heated to 450 deg. C. for more than 105 minutes; too long or too short heating yielded a metallurgically poor coke. The question is whether the suitable conditions can be applied in practice; the paper does not indicate the scale on which the experiments were conducted.

ON THE COOLING OF STEEL IN INGOT AND OTHER FORMS.*

By J. E. FLETCHER, Dudley.

DURING recent years there has been considerable advance in our knowledge of the behaviour of metals during cooling from the liquid state, and as regards steel the special problem of ingot solidification and cooling has deservedly received attention.

The practical work of Brinell and Wahlberg, Harmet, Talbot and later the results of Sir Robert Hadfield, Brearley and Kilby, together with the investigations carried out by Professor Howe, Dr. Burgess and Dr. Stead, have helped greatly the production of sound ingots.

There is even yet, however, need for further investigation of the laws which govern the freezing and cooling of steel in metal and sand moulds, and it is with this particular side of the subject that the present paper attempts to deal.

It is now generally recognised that steel is an approximately homogeneous mixture of iron-silicon or iron-silicon-nickel crystals or crystallites more or less carbonised by iron, manganese and chromium carbides; of migratory sulphides of manganese and iron; and of phosphide of iron, the mixture being accidentally but unavoidably permeated by occluded gases and by oxides and silicates of iron and manganese to a greater or less extent.

Wahlberg and Brinell showed that the presence of silicon, manganese and aluminium influence the formation of blowholes and "piping" and hinted that temperature of the casting influences the resulting ingots.

Harmet, by rapidly freezing the steel in the thick moulds necessary for his process and by "force-closure" of the sides of the ingot by a kind of "wire-drawing," extruded the central liquido-plastic core of steel, simultaneously expelling much of the gases liberated during crystallisation. Thus the contractional cavity or "pipe" was mechanically filled with liquid metal, and finally a solid ingot resulted. A similar result was obtained by Rodger by means of side pressure on the two opposite sides of a rectangular section mould.

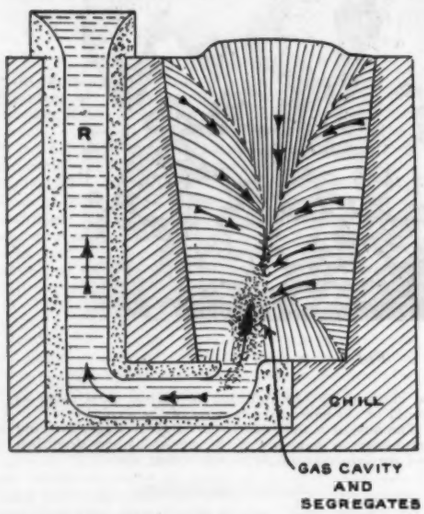


FIG. 2. WHITE IRON INGOT. TOP-POURED INTO IRON MOULD CONTAINING LIQUID SLAG. SLAG DISPLACED ESCAPED BY RISER R. GAS ESCAPE PATHS INDICATED BY ARROWS.

By keeping hot the top or head of the ingot Sir Robert Hadfield, Riemer, and others, retain sufficient liquid metal in the top or feeding head to descend into the "pipe" cavity as it forms, allowing the gases to escape the while. A solid ingot results, or at least an ingot whose comparatively short feeding head alone contains the "pipe."

Messrs. H. and W. Brearley, whilst pointing out the effectiveness of properly-shaped ingots and the advantage of hot feeder-heads, drew certain conclusions respecting the progressive freezing of the steel and the formation of "pipe," which require further investigation before final acceptance. The use of the stearine ingot, whilst very admirably illustrating the two types of crystalline structure within the ingot, viz., the chill crystals radiating from the mould contact surface, and the secondary or haphazardly orientated crystals of the mass interior, largely masks the effects of differential rates of cooling such as take place in masses of steel at high temperatures. The stearine, moreover, does not clearly illustrate the freezing of metallic liquids charged more or less with occluded gases, which undoubtedly play an important part in the formation of the "pipe" cavities and influence the volumetric contraction.

In his further comments on the production of comparatively slag and gas-free steel, and on the correct methods of casting ingots, Mr. Kilby has described defects which are again directly connected with the chilling action of the mould and the production of a perfect ingot skin. In a more recent paper Mr. Kilby has given further proofs of his contentions, and has shown how carefully timed speeds of teeming are conducive of the best results, skin defects being minimised and coincident forging and rolling troubles eliminated.

FIG. 1.

CONTRACTION AND PIPE IN INGOTS.

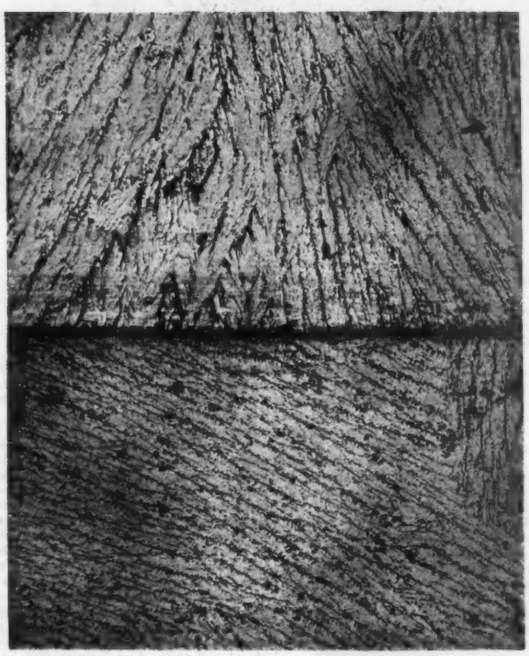
It is indisputable that molten steel, no matter how carefully melted, contains a very considerable volume of gas in suspension. The reactions which take place during the refining of the charge, under the slag blanket, are largely brought about by the oxidation of the carbon in the pig-iron or scrap. It is to be remembered that the volume of carbon monoxide liberated from the time of melting to that of finishing is (at 1,500 deg. C.) roughly 200 times that of the molten charge, and that the rate of gas ejectment is greatest at the bath surface, where, in contact with the reactionary slag and at the point of maximum temperature, the exchanges are most rapid. The tendency, under the high superheat conditions at the slag contact surface, is for the highest carbon-saturated metal to rise and for the comparatively pure iron crystalline grains to sink to the bottom of the bath. This tendency automatically assists the refining process.

It is indisputable, however, that considerable quantities of gas must be retained even in well "killed" steel, and the intimacy of FeO in the reactions involves definite inclusion of this oxide and possibly Fe_2O_3, either in solution or mechanically suspended between the semi-fluid or fluid(?) crystals of iron, or maybe occasionally as definite silicates. In the puddling furnace the variability of slag composition at a given moment during the concluding portions of the "boil" is very noticeable, one portion of the bath being often vigorously boiling whilst another is relatively quiet and the slag varying in silicate content. The composition of the spongy ball taken from the portion of the bath which first "comes to nature" is often very different from that of the ball made from the final refined product of the same bath, the slags and gassy nature of the two balls being different in physical character and composition.

In the steel open-hearth there must be similar heterogeneity; a difference in gaseous and oxide inclusions between the surface metal and that nearest the bottom of the bath. The finishing additions must further influence these gaseous and oxide inclusions and lead to reactions which continue in the fluid metal within the ladle and ingots up to the time of freezing. In the shallow baths of hot working furnaces the superheat conditions may easily be such that there is over-refining of the metal where, lying thinly over the banks of the hearth, excessive oxidation takes place, leading to considerable gas evolution when, later, the over-oxidised metal is mixed with the more highly carburised portions in the ladle.

From many observations of the behaviour of such metal in both ingot moulds and in the sand moulds for steel castings the author is driven to the conclusion that the phenomena of contraction and shrinkage are largely bound up with this question of gas inclusion. It is well known, for instance, that the feeding of a heavy casting is accompanied by vigorous gas escape through the feeding head. A so-called shrinkage cavity is thereby being filled with molten metal, the gaseous contents of the cavity being ejected through the head.

INGOT SIDE B.



BOTTOM FACE ON INGOT A.

FIG. 3. EUTECTIC PLATES IN WHITE CAST IRON. 4.2 PER CENT. C.
A. SECTION THROUGH PLATES OF EUTECTIC PARALLEL TO BASE OF MOULD.
B. SECTION THROUGH PLATES OF EUTECTIC PARALLEL TO SIDE OF MOULD.
FLOW STRUCTURE IN B INDICATED BY ARROWS.
THE TWO SECTIONS ARE TAKEN AT SAME POINT IN LOWER EDGE OF INGOT.

Steel or cast-iron when highly superheated above their melting-points have higher coefficients of contraction than similar metals melted with but little superheat; the need for cooling down in the ladle before casting overheated steel or cast-iron is well known as an antidote to excessive shrinkage or piping troubles.

The repeated annealing of large steel castings will bring about permanent reduction in volume, as instanced in the case of a number of cast steel rings about 16 ft. in diameter which by repeated annealing were reduced from 1¼ in. to 1⅛ in. in diameter without appreciable loss in weight or excessive scaling. This would appear to suggest that the gases imprisoned between the intercrystalline boundaries escaped by way of the casting skin and thus allowed a closer crystalline arrangement to persist.

A number of long cast steel pump rods cast on the flat and provided with a heavy feeding head at one end only were about 45 ft. long and contracted fully 10 in. The entire contraction was towards the feeder-head end of the rods, which end remained stationary. When

* Paper read before the Iron and Steel Institute, on Friday, September 13, 1918.

two feeder heads were employed, one at either end, the contraction was equally divided in the direction of the two feeders, but trouble was experienced by reason of the contractional nip between the two heads, and fracture occurred before the sand could be removed so as to allow free contraction between the heads.

This and similar experiences with other large castings suggests the connection between gas escape during the freezing and feeding of castings and contraction. One may go further and state that it is safe in foundry practice to regard the contraction of a casting as always less massive sections draw their feeding metal from the neighbouring heavier and more massive portions of the casting.

Cases have been known and observed where cast blocks of mild steel over a ton in weight (thick short slabs of rectangular section cast on the flat) have cooled without any trace of pipe, have proved solid and clean, and have when measured shown less than half the normal coefficient of contraction. In such cases the steel had accidentally, through nozzle stoppage, become nearly frozen in the ladle, and was only just "live" enough to fill the mould

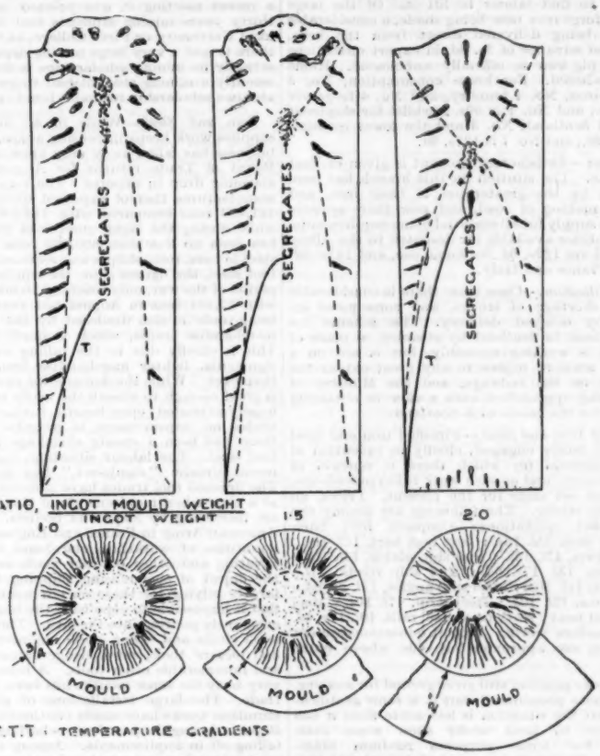


FIG. 4. FLOW STRUCTURES.

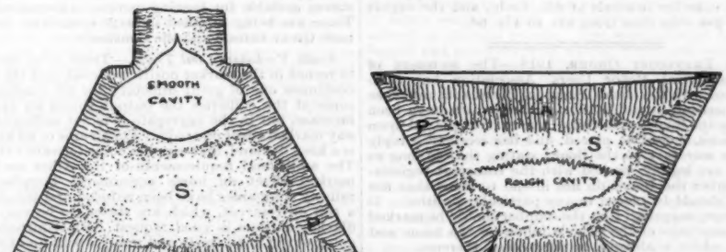


FIG. 5. SLAG INGOTS CAST IN IRON MOULDS. S = SECONDARY CRYSTALS. P = PRIMARY CRYSTALS. NOTE ANNEALING EFFECT ON PRIMARY CRYSTAL ZONE AT A, SECONDARY CRYSTALS FORMING.

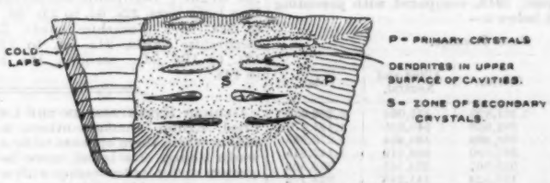


FIG. 6. FLUE CINDER INGOT, CAST SLOWLY.

following the direction of the liberated gas streams as they flow towards the mass centres and feeding heads, the portions last to solidify, and to take the view that contraction may be largely due to the escape and shrinkage of occluded gases during the freezing of the metal.

By placing the feeder heads at such positions as will enable the gases readily to escape, and by keeping the feeders hot and active, thus securing the filling, by molten metal, of the cavities which a moment before were filled with gas, uniform contraction is promoted.

Wherever a massive casting section is badly fed and "shrinkage" cavities occur, the rate of contraction of the massive portion is less than that of the thinner and better-fed sections adjacent to it. In reality, then the without rising into the feeder head. Apparently, during the prolonged stay in the ladle, occluded gases had escaped, hence the contraction due to gas escape from, and gas cooling within, the cast mass was correspondingly reduced.

Again, the contractional coefficient is greatest in the upper portion of a casting. Long castings vertically cast contract most in the upper portions, the pressure head being obviously accountable for the difference.

In a casting 10 ft. long the liquid pressure head compressing the imprisoned gas bubbles at the bottom of the casting is about 35 lb. per square inch greater than that at the top. Hence, if it be conceived that all the gases liberated within the metal during freezing become entrapped the bubbles in the lowest zone occupy less than one-third of the volume occupied by bubbles of similar weight in the upper zone of the casting. Let it be assumed that the difference in volume of the molten steel at, say, 1,600 deg. C. and the cold ingot or casting at 20 deg. C. is accounted for entirely by the shrinkage in volume of the occluded gases. Taking the mean linear contraction at 0·2 in. per foot the ratio :—

$$\frac{\text{Volume of liquid steel at 1,600 deg. C.}}{\text{Volume of solid steel at 20 deg. C.}} = 1{\cdot}05.$$

an ingot 12 in. square by 10 ft. long (when cold) would contain 870 cub. in. of gas when molten. When cooled to 20 deg. C. the gas volume would be reduced to 138 cub. in. This volume reduction corresponds with a linear contraction of 0·17 in. per foot. In such a casting the effect of liquid pressure head would be to increase the relative imprisoned gas volume gradually from the base to the top of the ingot, the mean reduction per cubic foot of ingot metal being :

$$\frac{870 - 138}{10} = 73{\cdot}2 \text{ cub. in.}$$

The top cubic foot would shrink 97·6 cub. in., whilst the bottom cubic foot would shrink 48·8 cub. in. The corrected contractions (linear) would then be at top 0·19 in. per foot, and at the bottom 0·14 in. per foot. In an actual casting of similar size 0·22 in. per foot (mean) has been observed, or 33 per cent. more than that calculated, on the supposition that all the contraction is due to the cooling of occluded gas. Such estimates lead one to conclude that two-thirds of the contraction may be due to such cooling, the remaining third being due to intercrystalline contraction or to the escape of a portion of the occluded gases.

Repeated researches on gas occlusion have shown that all steel and cast-iron in the cold state contain a very considerable volume of occluded gas, and it is obvious that as most ingots have a liquid pressure head of at least 15 lb. per square inch experiments even under *vacuo* conditions cannot exhaust all the occluded gases. There is a further possibility that intercrystalline cohesive forces further compress the imprisoned gases so strongly as to prevent their exhaustion by vacuum methods. This intercrystalline grip may account for much gas expulsion by way of the crystal boundaries during the freezing of the metal.

It is not certain that metals homogeneously solid (if such exist) do actually contract during cooling, and it may be safe to hazard the statement that no cast metals are gas free. This is certainly true of cast-iron and cast steels. Mr. Osmond drew attention to the fact that water from which the occluded vapour had been exhausted, when frozen in a glass tube, did not burst the tube; whereas water containing vapour in suspension and similarly frozen caused fracture of the tube. It may be that the presence of occluded gases is related to the phenomenon of dilatation at the recalescence and often at the freezing points of cast alloys and metals.

In the realm of foundry practice it is certain that when castings are badly fed and when the insufficient feeding heads are frozen over before the more massive portions of the castings become solid shrinkage cavities are inevitable, and great and general trouble occurs through the fissuring of the external skin as well as from internal ruptures. Almost invariably it is easy to trace the influence of internal gas pressure, which is often high enough to cause the gases to burst through from the cavity to the outer skin.

It would appear from such considerations that the function of occluded gases in the mechanism of freezing of iron and steel and other metals should not be overlooked. It is useful practically to follow the track of the gases as the various constituents of steel solidify in the ingot.

Growing first normally to the cooling surfaces of the mould the primary austenitic crystallites as they freeze eject the gases they contained when liquid into the surrounding mother liquor. Forcing their way between the dendritic branches and stems, increasing in volume and the smaller bubbles coalescing during the advance, they strive to reach the mass centre of the ingot. The smaller skin crystallites growing rapidly close up their ranks in the rear, driving before them the gas streams as the envelope thickens. If the chilling action of the mould is sufficiently rigorous the gas streams appear to possess enough directive power to control the position of the axes of crystallisation of the secondary crystals, as in the case of slightly hypo-eutectic cast irons especially those high in manganese and low in silicon content. The mother liquor into which the primary crystallites grow becomes more and more gas charged, and hence less dense; the growing dendrites droop and break off as they sink in the lighter liquid of the ingot interior, beyond which point the new crystallites forming have their axes in haphazard and confused directions. The gases, however, largely retain their direction, tending to reach the axis of the ingot and rising the while (Fig. 1, page 342). Such gases as are not entangled and imprisoned between the growing arms of the crystallites approach the axis and ascend, each layer of metal adding to the volume of the pipe. If the upper portion of the ingot be kept hot the gases forming the pipe will escape to the air or into the hot-top "feeder" head of the "Hadfield" type.

The segregatory constituents are driven along with the gas streams. If these streams are hindered and become pocketed anywhere, as in the corner spaces of polygonal ingots, or within the planes which bisect the corner and base pyramid angles, segregates are found, encouraging incipient freezing in the zones, immediately enveloping them, where they are ready to carry out their evil functions in later "ghost" troubles in the rolled or forged product. It may be further noted that if the gas exit is at the side of a casting instead of (as in an ingot)

at the top, the gas streams, according to their strength, give distinct direction to the crystallite axes in the direction of the feeding mass or head, wherever that may be. The author has observed numerous instances where the dendritic axes have been drawn downwards towards feeder heads whose conduits have been near the bottom of the castings. The general direction of the axes was of course normal to the mould surface, but here there was distinct deflection downwards, Fig. 2. All such illustrations which occur daily in foundry work point clearly to a much more important function of the escaping and occluded gases than is usually accorded them in the recognised descriptions of the mechanism of metal solidification.

In casting small ingots of white iron, of approximately eutectic composition, in chill moulds, the crystals freezing normally to the mould surfaces are plates of eutectic, each apparently rhomboidal in form with a central core in which minutely thin plates of iron carbide in an austenitic matrix, roughly parallel to the long flat sides of the rhomboidal plates of the eutectic, have distinctive flow structures, Fig. 3, page 342, and Fig. 4. The axial direction of each plate crystal is approximately normal to the chill surface, and is deflected apparently by gas flow influence towards the hot mass centre. If there be a cavity or pipe in the ingot the axes of the plates point in the direction of that cavity, and the core crystals within the main crystals of the eutectic have themselves a flow structure which is always directed towards the pipe, cavity, or mass centre of the ingot. This statement should be qualified by saying that the definite orientation of the plate crystals persists only so long as the chilling influence of the mould surface is sufficiently powerful, or, as will be demonstrated later, the temperature gradient of cooling remains sufficiently steep.

Before leaving the subject of gas ejectment from molten masses, mention should be made of interesting phenomena which may at any time be observed during the freezing of iron and steel castings.

The upper surface of an open sand cast plate or that of an ingot cast in a thick mould (without hot-top feeder) often clearly shows rings or polygons of gas bubbles concentric with the mould form. The edges next to the mould remain clear of bubbles and shrink downwards towards the mould surface, leaving a rounded surface free from gas bubbles, sometimes extending an inch inwards from the mould. The outer rings of bubbles are of small size; as they approach the ingot or plate centre they increase in size but are fewer in number and are spaced farther apart. In the top surface of a square ingot the bubbles rise most copiously along the diagonals, and in certain alloy steels and white iron the upper surface shrinks, leaving a hollow of inverted pyramid form along the corners of which when cold the bubble paths can readily be traced.

The pickling in acid of a seemingly solid open sand plate yields a porous surface, and very clearly defines the progress of freezing in the neighbourhood of the corners and edges. By spraying cold water on local spots at the surface of a molten open sand plate the gas bubbles may be suppressed in the chilled areas, but around them in the adjacent molten metal others burst out more vigorously. Anyone who has had experience in the pickling of steel castings preparatory to galvanising will have noticed the porosity of the envelope, especially near the roots of re-entrant angles as where ribs join plane surfaces and in the neighbourhood of massive sections which have not been perfectly fed.

The influence of occluded gases can be well studied by means of ingots and other forms cast from flue cinder from puddling or pile reheating furnaces. The rapid freezing of this material very plainly indicates the gas function, producing "pipe" phenomena with volcanic effect, the top crust often being raised by the gas pressure within the hidden "pipe." By locally heating the central portion of the crust of a flue cinder ingot the feeding effect is rapidly produced; during the period of feeding gas escapes copiously and ceases when the "pipe" is filled. The primary chill crystals radiating from the mould surface and the secondary crystals of confused orientation are well illustrated in Fig. 5, which shows two ingots of ferrous silicate slag. The effect of casting conical moulds with the small end upwards and *vice versa* on the "pipe" contour is very clearly indicated.

An ingot of fine cinder run very slowly illustrates the behaviour of steel when slowly teemed into a thick mould, exaggerating the defects brought about by excessively slow teeming. The effect of the atmospheric chilling on the rising surfaces of the liquid and of the freezing action of the mould contact is seen in the shrinking of the successive strata at the ingot surface, just as in the case of the open sand plate already mentioned. Each layer of molten metal overruns a lower one whose edges are already frozen, hence a lap occurs, the two surfaces being only partially welded together. In some cases the overhanging "lap" can be prized or chipped off, Fig. 6.

Further, the liberated gases cannot get away to the top of the ingot and become entrapped in lenticular horizontal cavities, which are more or less lined with primary crystals. The nearer the top of the ingot the larger the cavities; the lower ones being smoother at their surfaces and rounded in form, clearly indicate gas pressure. Fig. 6 is a sketch of a typical ingot section from a flue cinder wagon which was filled gradually by dribbling ferrous silicate slag.

(To be continued.)

BRITISH CHAMBER OF COMMERCE, BORDEAUX COMMITTEE.—The British Chamber of Commerce, Paris, has formed a committee in Bordeaux, composed of local members of the Chamber. The objects of forming the committee is to enable the Chamber to deal more effectually with local matters, to increase the utility of the Chamber, and to enlarge its sphere of action.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Pressure for delivery of Cleveland foundry iron is unabated; home consumers complain of short supplies of this quality, whilst exports are maintained on a heavy scale. Blast furnaces are working only moderately well, with the result that they are producing more inferior iron than better quality. Makers have some small stocks of foundry pig-iron, but it is difficult to find labour to lift it. Of the large quantities of forge iron now being made, a considerable proportion is being delivered direct from the beds. The anticipated advance of 3*s.* 9*d.* in export quotations of Cleveland pig-iron is officially announced. Home prices are unaltered. For home consumption, No. 3 Cleveland pig-iron, No. 4 foundry, and No. 4 forge are all quoted 95*s.*, and No. 1 is 99*s.*; whilst for shipment to France and Scotland, No. 3 and the lower qualities are now 122*s.* 9*d.*, and No. 1 is 127*s.* 9*d.*

Hematite Iron.—Satisfactory account is given of East Coast hematite. The situtions in this branch has been much relieved by the greater use of basic iron, and scrap for the making of steel, and now there appears to be adequate supply for all essential home requirements, and large quantities available for despatch to the Allies. Nos. 1, 2 and 3 are 122*s.* 6*d.* for home use, and 147*s.* 6*d.* for export to France and Italy.

The Truck Situation.—Once more there is considerable complaint of shortage of trucks, and consequent inconvenience by delayed delivery. The scheme for conveying pig-iron to Scotland by steamer, in place of rail transport, is working smoothly, but is not on a heavy enough scale to relieve to any great extent the great pressure on the railways, and the Ministry of Shipping is being approached with a view to obtaining more tonnage for the trade with Scotland.

Manufactured Iron and Steel.—Finished iron and steel works are very busily engaged, chiefly in execution of shipbuilding material for which there is renewal of pressure for delivery, and as such work takes precedence, other orders are set aside for the present. Prices, all round, are very strong. The following are among the principal market quotations:—Common iron bars, 14*l.* 15*s.*; best bars, 16*l.* 15*s.*; best best bars, 16*l.* 15*s.*; best best best bars, 17*l.* 15*s.*; iron ship plates, 15*l.* 10*s.*; iron ship angles, 13*l.* 17*s.* 6*d.*; iron ship rivets, 21*l.*; steel ship plates, 11*l.* 10*s.*; steel ship angles, 11*l.* 2*s.* 6*d.*; steel boiler plates, 12*l.* 10*s.*; steel strip, 17*l.* 10*s.*; steel hoops, 18*l.*; and heavy sections of steel rails, 10*l.* 17*s.* 6*d.*—all f.o.b. at makers' works. Export quotations are not fixed, but they are approximately 40*s.* above home prices.

Coke.—The coke position still gives ground for anxiety. Shortage continues pronounced, but it is some gratification to hear that the situation is less acute than it has been. Deliveries to local works show some little improvement. For home purposes medium blast-furnace coke is 33*s.* at the ovens, and low phosphorus quality 35*s.* 6*d.* at the ovens. There are buyers of foundry coke for neutrals at 65*s.* f.o.b., and the export price of gas coke runs from 45*s.* to 47*s.* 6*d.*

ROAD TRANSPORT ORDER, 1918.—The secretary of the Commercial Motor Users' Association has communicated with the Road Transport Board with reference to the position in which the numbers which have been issued by the Board, and which have to be displayed upon the vehicles, should be placed, and has received a reply from the secretary to the Board stating that so long as vehicles are legibly marked with the transport registration number the Board do not intend to insist that the number should be placed in any particular position. It is, however, suggested that the number should be marked on the near side of the vehicle following the name and address, which is already, in most cases, thereon.

LOSSES OF MERCHANT TONNAGE.—The Secretary of the Admiralty makes the following announcement:—The losses of British, allied and neutral merchant tonnage due to enemy action and marine risk during the month of August, 1918, compared with preceding periods, are set out below:—

Gross Tonnage.

Period.	British.	Allied and Neutral.	Total.
Second quarter, 1917	1,361,870	875,064	2,236,934
Third quarter, 1917..	952,938	541,535	1,494,473
Fourth quarter, 1917	782,889	480,954	1,272,843
First quarter, 1918..	697,590	449,519	1,142,815
Second quarter, 1918	625,361	334,145	959,506
July, 1918	182,524	141,248	323,772
August, 1918.. ..	176,401	151,275	327,676

The tonnage of steamships of 500 gross tons and over entering and clearing United Kingdom ports from and to ports overseas was as under:—

Period.	Gross Tons.
January, 1918	6,836,663
February, 1918	6,326,965
March, 1918	7,295,620
April, 1918	7,040,309
May, 1918	7,777,843
June, 1918	7,430,386
July, 1918	7,718,806
August, 1918	8,158,639

This statement embraces all United Kingdom seaborne traffic other than coastwise and cross-Channel. If British losses from enemy action alone are considered, August is better than any month since September, 1916.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Mining Prospects in Doncaster Area.—At a meeting of the Doncaster Technical College this week, where Mr. T. H. Mottram, C.B.E., distributed the prizes to successful students, the chairman announced that immediately at the conclusion of war eight new pits would be sunk in the neighbourhood.

Mining Scholarships.—An interesting point is engaging the attention of the Sheffield Education Authority. At a recent meeting it was pointed out that though for thirty years mining students had been trained in the local University or Firth College, at the former of which there is now a very large mining department, there were actually no mining scholarships in the district, and that recently a mining student had to go to South Wales to obtain a scholarship to enable him to continue his studies.

Iron and Steel.—While in all departments of war supplies work keeps increasing apace, in other directions business has fallen away very appreciably of late. The Board of Trade returns for August reveal a further alarming drop in exports. The total of iron, steel and manufactures thereof exported during the month was 161,893 tons compared with 214,290 tons a year ago, while during the eight months of the year the decline has been no less than 600,000 tons. In manufactured steel in bars, rods, shapes and sections, including Sheffield tool steel, the figures show the smallest total during the period of the war, only reaching 10,500 tons, as compared with 52,594 tons in August last year. The position of local trade is also disclosed by the returns of railway merchandise traffic, which is much below the normal. This is chiefly due to the falling away in heavy consignments, lighter merchandise being in greater bulk than ever. While the demand for steel for shell and guns is great enough to absorb the whole of the output of the hugely-extended open-hearth furnaces, in the lighter trades no improvement is recorded. For weeks past there has been a steady shrinkage in the demand for tool steel. The labour situation, consequent upon the recent drastic "comb-out," has become very acute. The finished tool trades have suffered severely, and that at a time when requirements of this branch of industry are increasing by leaps and bounds. The needs of the American Army in France and England are great. Vast quantities of workshop and hand tools used for excavating and other outdoor work are required. With the object of economising shipping the Americans are largely relying for these on our workshops, and makers find it impossible to cope with the huge orders which are constantly pouring into the city. These include not only twist drills and other small engineers' tools, but edge and joiners' tools, saws, sledge hammers, picks, shovels and innumerable other tools. A branch which has been very busy for some months has been the heavy foundry trade. The large installations of plant for steel and munition works have made continuous calls upon them. Reports during the past few weeks, however, show a slight falling-off in requirements. Among the lighter foundry work which has come to hand in increasing volume with the approach of winter are orders for slow combustion stoves suitable for heating camps, canteens and works. These are being supplied in large quantities throughout both Great Britain and the Continent.

South Yorkshire Coal Trade.—There is no new feature to record in the market position of coal, and the situation continues one of great difficulty for all consumers. At some of the collieries the output shows an appreciable increase, but in the aggregate it is not sufficient to have any marked effect on trade. For steams of all kinds there is a keen demand, and supplies come forward very slowly. The additional requirements of the Allies are having a marked effect on home consumers. Supplies to the railway companies have been reduced and this is causing a run on reserves, which are stated to be very limited. Slacks continue in good request. Blast-furnace coke is going out of hand freely and many works find themselves short of their requirements. Gas and household coal are very difficult to obtain, and the process of winter stocking is very slow. Prices at the pit are as follow:—Best branch handpicked, 27*s.* to 28*s.*; Barnsley best Silkstone, 27*s.* to 27*s.* 6*d.*; Derbyshire best brights, 25*s.* to 26*s.*; Derbyshire house coal, 22*s.* 6*d.* to 23*s.* 6*d.*; Best large nuts, 22*s.* 6*d.* to 23*s.* 6*d.*; small nuts, 21*s.* 6*d.* to 22*s.* 6*d.*; Yorkshire hards, 22*s.* 6*d.* to 23*s.* 6*d.*; Derbyshire hards, 21*s.* 9*d.* to 22*s.* 9*d.*; best slacks, 18*s.* to 19*s.* 6*d.*; seconds, 16*s.* to 18*s.*; smalls, 13*s.* to 14*s.*

GERMAN ENTERPRISE IN THE UKRAINE.—The firm of Fried. Krupp, amongst others, is generally ready to step in where there appears to be a chance of a business worth doing. Its latest move is the formation of a concern under its leadership with a capital of 20,000,000 marks and an additional guaranteed capital of 80,000,000 marks for the purpose of exploiting Ukraine industrially. A number of undertakings in the iron and steel industry in the machinery and electrical branch are also interested in the venture. At the same time a number of banks and financiers have formed another syndicate for the exploitation of Ukraine financially, and, it is added, in the matter of railway construction. The latter concern so far has only a capital of 5,000,000 marks, and its work, in the first instance, will probably be confined to a close study of the country and the possibilities it offers. The fact that the two concerns have not joined hands has caused some surprise, but the reason is stated to be that the banks wanted a concern which comprised all industries and did not find it expedient to co-operate with one which only represented a limited number. The two undertakings, however, are understood not to clash in their Ukrainian ventures.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—The extensive and continued activity in the steel trade in the West of Scotland has been an impelling force, and the efforts of all concerned are having such good effect that affairs are decidedly easier than for some considerable period. Indeed, so great has been the increase of output that the steel-makers are now in a position to consider some at least of the wants of ordinary mercantile consumers; while, in addition to this concession, a certain percentage of the tonnage is also available for shipment to neutral countries—Holland, for example, came in for a share of material for shipbuilding purposes. The disposal of the output, of course, remains to a great extent in the hands of the Superintendent for the Admiralty, this naturally relieving manufacturers from the onus of refusing old customers and others whom they might be willing to oblige in an emergency. Much satisfaction is felt that the home requirements have now been so fully met. The scarcity of fuel, and the difficulty of increasing the supply certainly give rise to much concern in the minds of steelmakers.

Malleable Iron Trade.—The demand for malleable iron is still so excessive that the supply falls considerably short and yet makers continue to be inundated with orders and inquiries. While Government work naturally has first place, demands are constantly being made for bolt and nut iron, for light rails and agricultural sections as well as for large quantities of material for French war purposes. All over the pressure for delivery is very great, and the entire plant available is running at its fullest capacity.

Scotch Pig-Iron Trade.—Pig-iron of all grades is in great request, with a specially brisk demand for hematite, every ton of which goes direct to the steel works, and all under Government control and allocation. Certain brands of foundry iron are scarce, but forge is more plentiful than it was. Under existing conditions the home demand is such that only very limited orders for export can be entertained. Prices are still firm and likely to remain so.

FERRO-CONCRETE BARGE BUILDING AT BARROW.—A ferro-concrete barge was launched at Barrow last Saturday. Its principal dimensions are: Length, 187 ft. 6 in.; breadth, 31 ft. 6 in.; depth, 20 ft. 9 in. This is the first of 10 similar barges now building for the Department of the Controller-General of Merchant Shipbuilding by the Ferro-Concrete Ship Construction Company, on the Mouchel–Hennebique system.

THE MILLING CUTTER MANUFACTURERS' ASSOCIATION.—Consequent upon a meeting held on the 18th inst., at the Midland Hotel, Manchester, of representative manufacturers of milling cutters, it has been decided to form immediately an association to be known as the Milling Cutter Manufacturers' Association, to deal with all matters interesting or affecting the makers of these tools. In view of the present conditions existing in this trade and for post-war purposes, it is to the general interest of all manufacturers of milling cutters to come together and to deal unitedly with important matters affecting their trade as a whole. The association will be glad to receive applications for membership from *bona fide* manufacturers of milling cutters, such applications to be addressed to the Secretary, Milling Cutter Manufacturers' Association, care of Sir W. G. Armstrong, Whitworth and Co., Limited, Openshaw, Manchester.

BRITISH EAST AFRICA.—A Bill dealing in a comprehensive manner with electric power supply is now awaiting its final reading in the Legislative Council of the Protectorate. The measure is designed to foster and promote bulk supply methods and to ensure standardisation. Public and local authorities must adopt the standards and specifications of the British Engineering Standards Committee. The standard system for the Protectorate will be three-phase at 50 periods, excepting for special purposes, and excepting the supplies to authorised distributors and for special purposes, the pressures of supply will be 415 volts and 240 volts. All apparatus to be used in connection with a standard system, by a licensee, must comply with these standards, and that which may be used by others on a standard system must be marked when usual or necessary as to its capacity or value, in terms of British standards. Practically every form of energy which industrialists in the Protectorate will require must be obtained from or by the conversion of electrical energy generated by water power, internal-combustion engines, or oil-fired boilers. Consequently a demand for apparatus is developing which should not be neglected by British manufacturers. The Government electrical engineer will be pleased to receive catalogues and other information, with prices where possible, relating to hydraulic, internal combustion, and steam types of prime movers, electric generators and motors, transformers, E.H.P. transmission-line materials, split phase and other control and switching apparatus, indicating and recording meters, testing and measuring apparatus, &c.; also relating to apparatus for any industrial application of electrical energy including farm and electro-culture equipment, electrolysers, ozonisers, automobiles, batteries and battery charging, coffee drying and roasting, steam raising, mashing and distilling, casting and welding, cement burning, domestic heating and cooking, and x-ray and electro-medical equipment, &c., &c. Inquiries from those interested are solicited, and should be addressed to the Government Electrical Engineer, Nairobi, British East Africa.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—Business on the local markets this week has been entirely dislocated by the railway strike. All the available supplies of coal have been commandeered by the authorities. Although no official statement has been issued giving precise details of the number of collieries rendered idle, it was estimated yesterday evening that about a third of the outputs which have recently been about 140,000 tons to 150,000 tons a day have been lost, and about 50,000 miners were even yesterday thrown out of employment and, owing to the impossibility of supplying to factories, &c., there were involved about another 50,000 men. At Cardiff traffic was kept open by the loyalty of the employees of the Taff and Rhymney Railway Companies. The delivery of pitwood and other essential supplies to the collieries are also held up and the inland market is completely disorganised.

Newport.—The position in regard to Monmouthshire coals is simply disastrous. As had been feared, the exhaustion of the supply of wagons and the withdrawal of their labour by railway traffic men have made it impossible for a great many pits to continue working, and the export trade is at a standstill. The deliveries of pitwood and iron ore are also seriously affected, while the forwarding of coal for the inland market has been enormously restricted.

TIGHTENING RUBBER TUBING ON GLASS.—When rubber tubing is used to join sections of glass tubes, a tight connection between the rubber and the glass is commonly produced by wrapping a single turn of wire round the rubber and twisting it. There is danger, however, that the wire may cut the rubber, whilst on the other hand a rubber tube which is slightly over size may fold and leave a leakage channel. A cord is better than a wire, but if too tightly drawn may cause the same trouble, especially at the knot. A simple combination device is proposed by C. C. Kiplinger in *The Journal of Industrial and Engineering Chemistry*, of August last. A stoutish copper wire is bent to a horseshoe or U of more than sufficient size. This U is slipped into a loop of stoutish cord so that the two parts form an 8; the cord is placed in position, and the U is used as a lever to twist the cord; when this is done, the U is turned through 180 deg. so as to bear gently against the rubber. To undo the joint, the U has simply to be bent back again.

RECOVERY OF SOLVENTS FROM AIR-VAPOUR MIXTURES.—The collodion solvents of which the Welsbach Company, of Gloucester City, New Jersey, U.S.A., makes use in its gas-mantle manufacture, are alcohols (ethyl and methyl), acetone and camphor; the proportions of these solvents may vary, but the plant for the recovery of the vapours has operated successfully for several years. At first the company dried the collodion in the open air; then the collodionised mantles were carried through chambers open at both ends, and finally drying chambers or boxes were adopted, through which the mantles are moved on wheeled trucks. The steam-heated boxes are lagged and provided with sliding doors, and each of the 14 boxes is an independent unit. The vapours from these chambers, we see from an article by E. L. Knoedler and C. L. Dodge in *The Journal of Industrial and Engineering Chemistry*, August, 1918, are delivered to the recovery plant at the rate of 450 cub. ft. per minute under a pressure of 1 lb. per square inch, and at a temperature of 80 deg. C., and contain about 4 per cent. by volume of solvents; the air is finally discharged into the atmosphere at 14 deg. C. and still contains 0·9 per cent. of solvents, so that 1 per cent. of the solvents is lost, but might possibly be utilised. The recovery plant consists of a large surface condenser acting as pre-cooler; a group of scrubbing towers, in which the vapours are scrubbed with water; receivers for the liquor obtained which is cooled by brine coils; pumps for circulating the liquor until it is sufficiently concentrated to be sent into the column still; this still, and an ice machine. In the pre-cooler the vapours circulate through the tubes which are cooled by the waste gases. The towers are arranged on the bell-and-seal system, and the vapours bubble through water at 5 deg. C.; the air (the waste gases just mentioned) escapes at 7 deg. C. The water which has taken up the vapours flows into catch basins and is circulated through the towers and basins for several hours until it contains 12 per cent. of solvents; at that concentration it is delivered into the still tanks; the water finally discharged from the still returns to the towers which are independent units like the drying boxes. The still, of copper, is built up of a number of sections arranged vertically above one another; below is the heating compartment, 36 in. in diameter and about as high, heated by a steam coil; over this are three distilling sections, 24 in. diameter, and seven more distilling sections, 18 in. diameter; these latter are provided with cooling coils which are connected in series and regulated by a throttle valve. The feed liquor is preheated in a tubular condenser through which the vapours from the 24-in. sections circulate. The still produces a condensed vapour mixture of from 97 per cent. to 99 per cent. The camphor settles in trays placed in the sections where the temperature ranges from 95 deg. to 75 deg; these trays are periodically drained; the remaining camphor is caught in a sump; the camphor is gained in press-cakes further to be purified. The cost of working a plant for the recovery of 65 gallons to 75 gallons of solvents per day of 8½ hours is estimated at 15 dols., the chief items being labour (1 man) 3 dols., steam 5·20 dols., fixed charges 8·75 dols.

NOTICES OF MEETINGS.

THE JUNIOR INSTITUTION OF ENGINEERS: NORTH-EASTERN SECTION.—Tuesday, October 1, at 7.15 p.m., at the Mining Institute, Neville-street, Newcastle. Annual general meeting.

THE INSTITUTION OF AUTOMOBILE ENGINEERS.—Wednesday, October 2, at the Royal Society of Arts, John Street, Adelphi, W.C., at 7.30 p.m. Mr. A. A. Remington will deliver his Presidential Address.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, October 4, at the meeting hall of the Institution of Civil Engineers, at 6 p.m., the annual Thomas Hawksley Lecture will be delivered by Dr. W. Cawthorne Unwin, F.R.S. Subject, "The Experimental Study of the Mechanical Properties of Materials."

WEIGHTS OF DERRICKS.—In an article published in *Contracting*, Mr. J. McCord gives particulars of the weights of derricks as used in the United States. He states that the standard guy derricks built by his company, equipped with tackles and guys weigh as follows: 32-ft. mast, 74-ft. boom, 8-ton capacity 12,000 lb.; 70-ft. mast, 60-ft. boom, 12-ton capacity 22,400 lb.; 83-ft. mast, 75-ft. boom, 20-ton capacity 33,300 lb.; 85-ft. mast, 75-ft. boom, 30-ton capacity 29,000 lb. and 30,900 lb. A wooden guy with 80-ft. mast, 75-ft. boom, 8-ton capacity, would weigh about 16,000 lb., and a corresponding stiff-leg derrick 22,000 lb.

PERSONAL.—Messrs. Ruston, Proctor and Co., Limited, Lincoln, announce that they have acquired the very old-established business of Messrs. Richard Hornsby and Sons, Limited, Grantham and Stockport, which is a concern of world-wide reputation. Their works are extensive, well equipped with modern plant and machinery, and occupying over 3,000 employees. The name under which the new combination will be carried on is Ruston and Hornsby, Limited.—Messrs. Ed. Bennis and Co., Limited, 28, Victoria-street, S.W. 1, announce that they have a large number of lantern slides dealing with the development and present practice in connection with automatic stokers, coal elevators, and conveyors, &c., which they will be pleased to loan to any responsible inquirer for lecture purposes.

CONSERVATION IN MANUFACTURING DROP-FORGED WRENCHES.—At a meeting of most of the drop-forged manufacturers of the United States of America, held at Buffalo, New York, on August 7, very material reductions of sizes, styles and finishes of drop-forged wrenches were agreed upon for the purpose of furthering the Government's conservation policy during the period of the war. The drop-forged wrench makers have arranged to discontinue immediately the manufacture of regular finished wrenches which will release a great deal of polishing and lacquering labour, reduce the necessary bins by one-third and effect a very great conservation. Possibly the manufacture of the "semi-finished" wrench, as such, may later be eliminated also; if so, there would be furnished in its stead a "war-finished" condition which would be its equal in efficiency but slightly different in appearance. It was further decided to purchase no more envelopes and no more boxes for packing except the few paper boxes necessary when furnishing wrenches in sets. All wooden boxes and all sample and display boards for advertising and sales purposes were eliminated. The lines retained as necessary are engineers' wrenches, check-nut wrenches, light cap-screw wrenches, hexagon box wrenches, square box wrenches, flat handle "S" wrenches, set screw wrenches, tool post wrenches, single-head socket wrenches, spanner wrenches, construction wrenches, structural wrenches, round handle track wrenches, car wrenches and light service wrenches, all of which have useful functions to such an extent as to make their elimination doubtful from the view-point of conservation.

CHEMISTRY OF GOLD AT HIGH TEMPERATURES AND PRESSURES.—Professor Harold H. Morris has been experimenting with gold solutions in a steel bomb in the hope of elucidating the conditions under which free gold is deposited in Nature. His bomb is a cylinder, 12 in. long, 3 in. in diameter, with a bore of 1¼ in. diameter; it is made of vanadium-chrome steel and electrically heated. He started from gold hydroxide; this body was decomposed when heated with water up to 322 deg. C. in the sealed bomb, and metallic gold was liberated. The presence of small percentages of inorganic salts lowered this decomposition temperature by 70 deg. C. in the cases of sodium and magnesium chlorides; but calcium chloride had the opposite effect. Gold chloride, prepared by dissolving the hydroxide in hydrochloric acid, was only decomposed when the critical temperature of water (about 365 deg. C.) was exceeded; in this case the presence of all the metallic chlorides mentioned raised the temperature of decomposition to 450 deg. or 460 deg. C., and this peculiarity is ascribed to the formation of double chlorides. When gold chloride was heated in the presence of a crystal of calcite ($CaCO_3$) or magnesite ($MgCO_3$), the mineral became beautifully plated with gold crystals, sometimes in fine octahedra, sometimes in dendritic forms; the appearance of the crystals changed with the mineral. This and the first-mentioned fact, that sodium chloride favoured the decomposition of gold hydroxide, whilst calcium chloride prevented it, seem to us the most striking features brought out. One would hardly expect that so closely allied salts would have different effects; in Nature both the chlorides would frequently be present together, and it would scarcely have occurred to geologists to pay particular attention to the presence of either of them. The experiments will be continued.

TURBINES AT THE LARDERELLO NATURAL STEAM POWER STATION.

CONSTRUCTED BY MESSRS. FRANCO TOSI, ENGINEERS, LEGNANO, ITALY.

(*For Description, see Page* 339.)

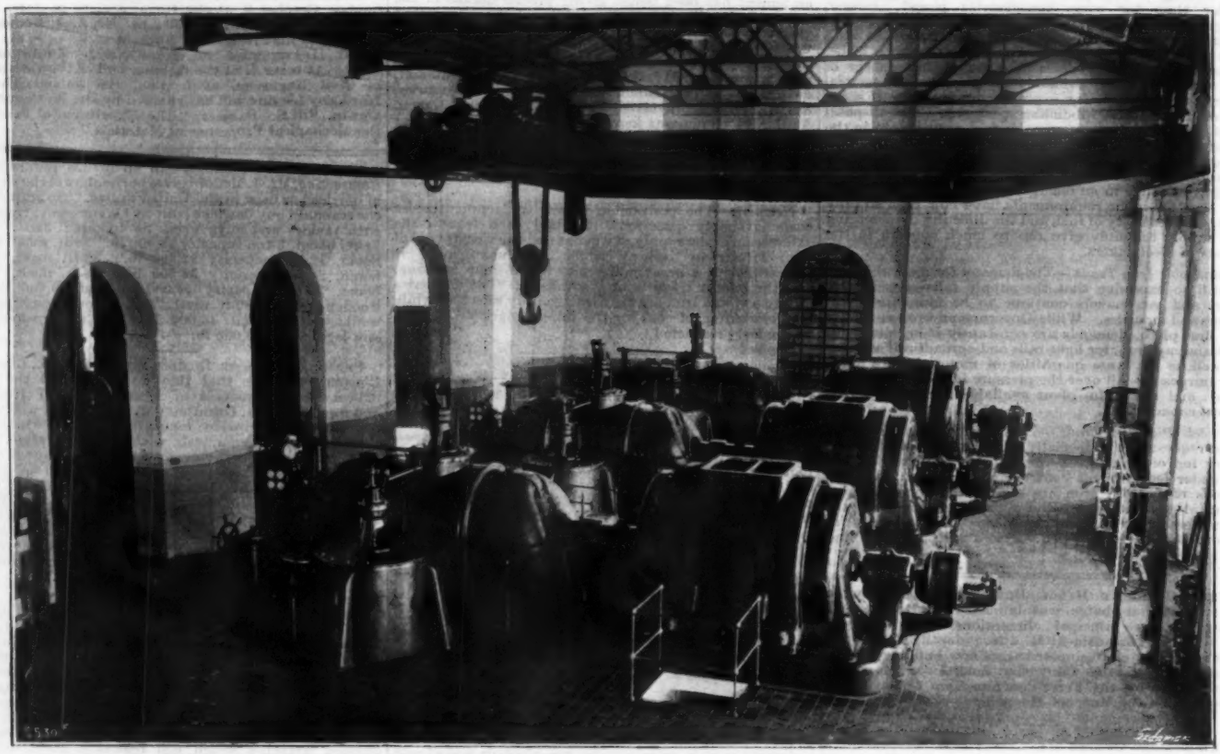


Fig. 12. Interior of Power Station.

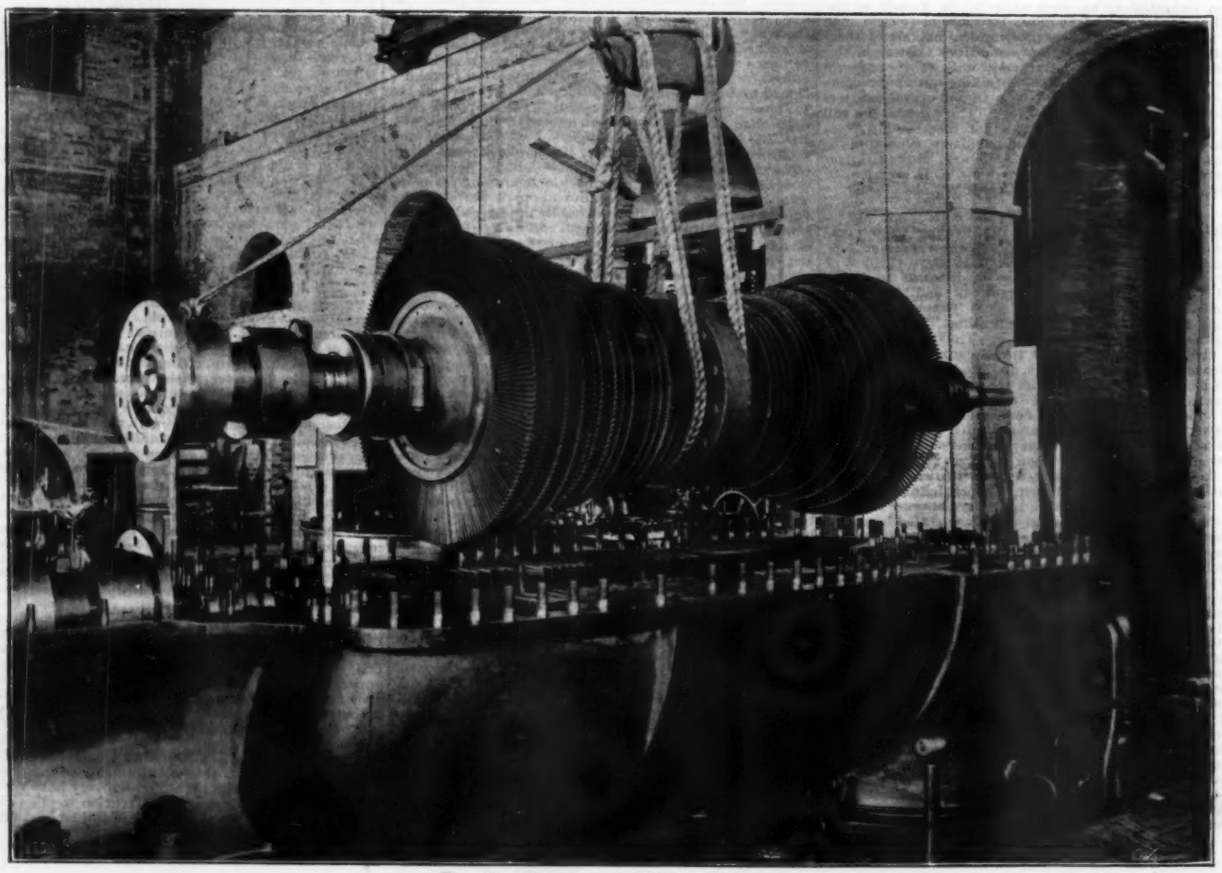


Fig. 13. Rotor of 2,500-Kw. Turbine.

LOW-PRESSURE STEAM TURBINES AT THE L[illegible]ER

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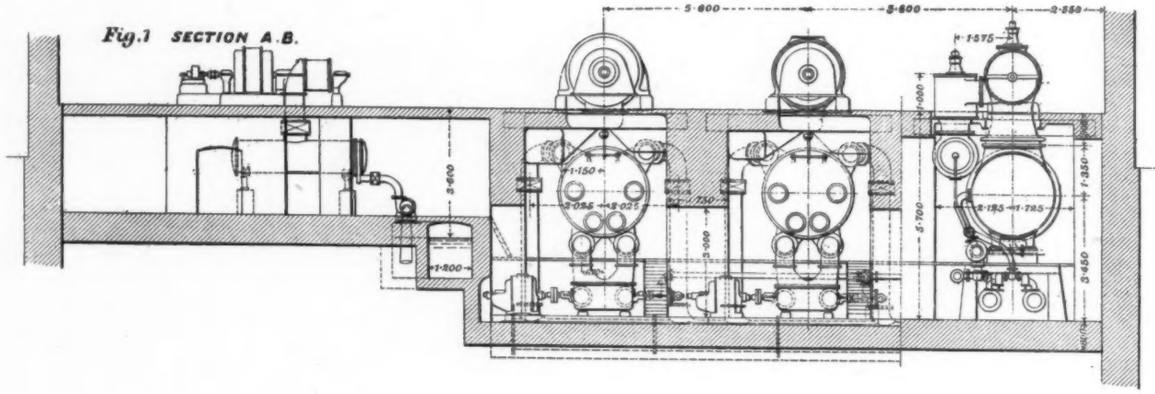

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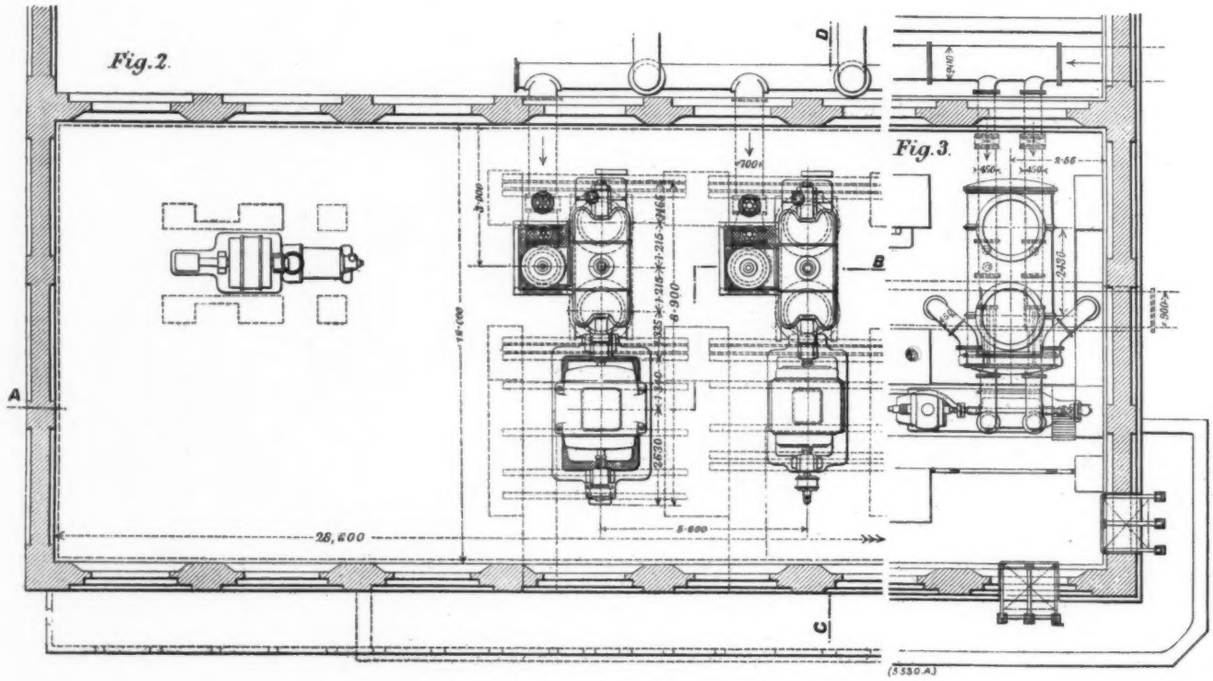

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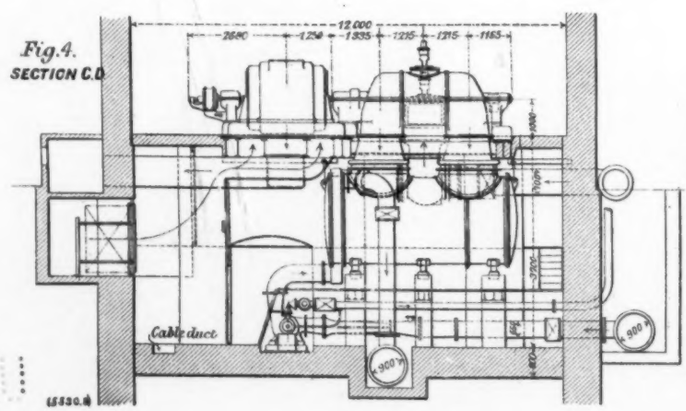

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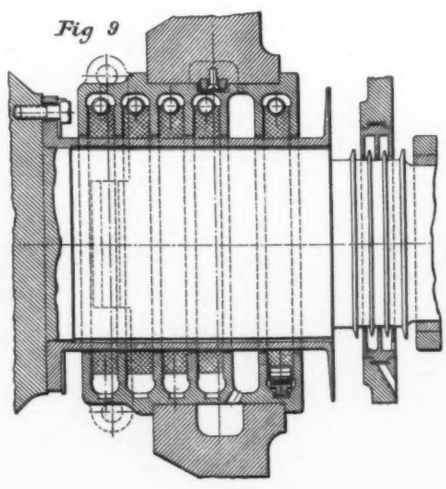

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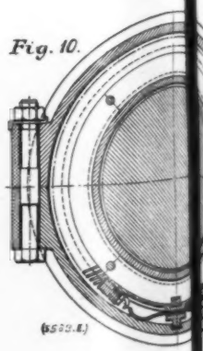
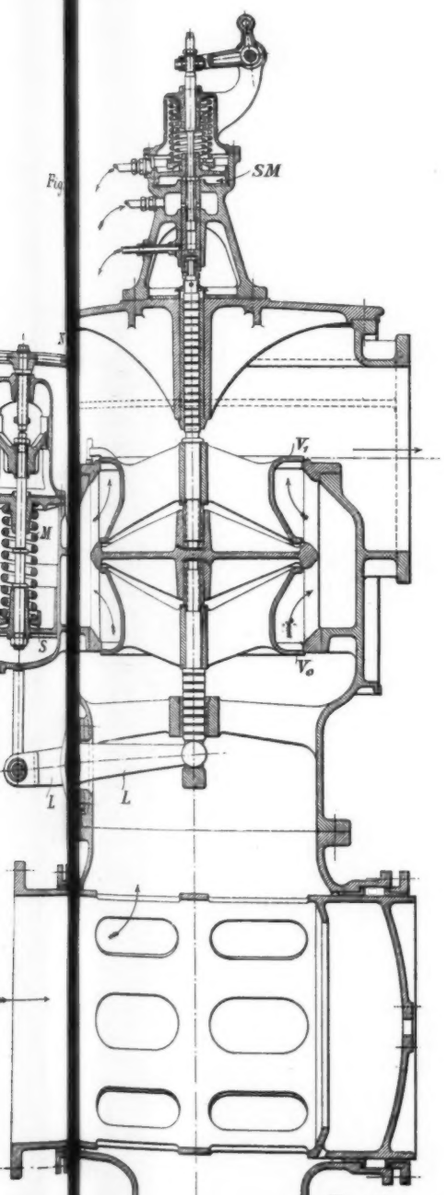


HE [B]ERELLO NATURAL STEAM POWER STATION.

SRS. FRA[TELLI] ENGINEERS, LEGNANO, ITALY.

(For Desc[ription] Page 339.)



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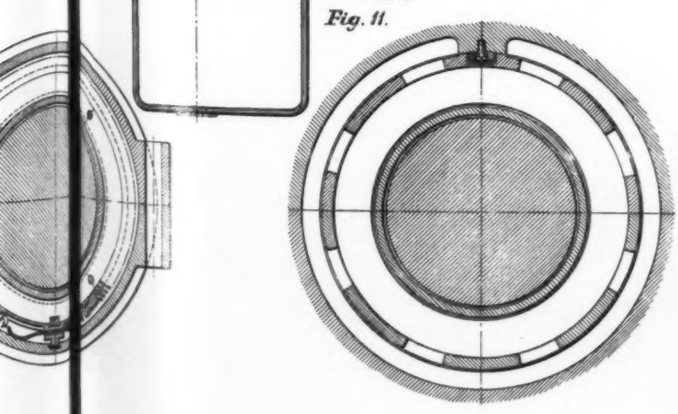

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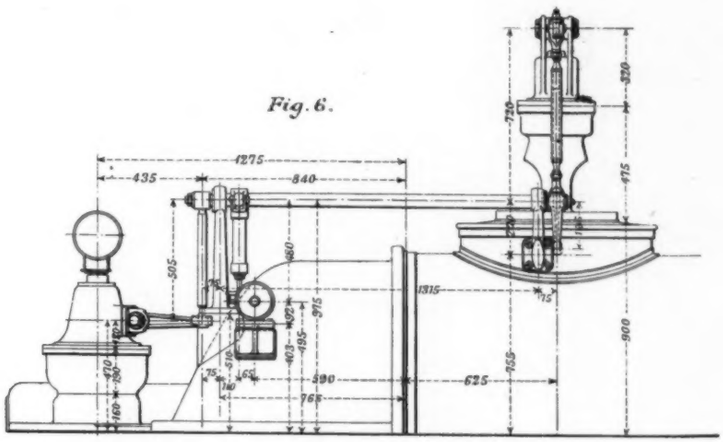

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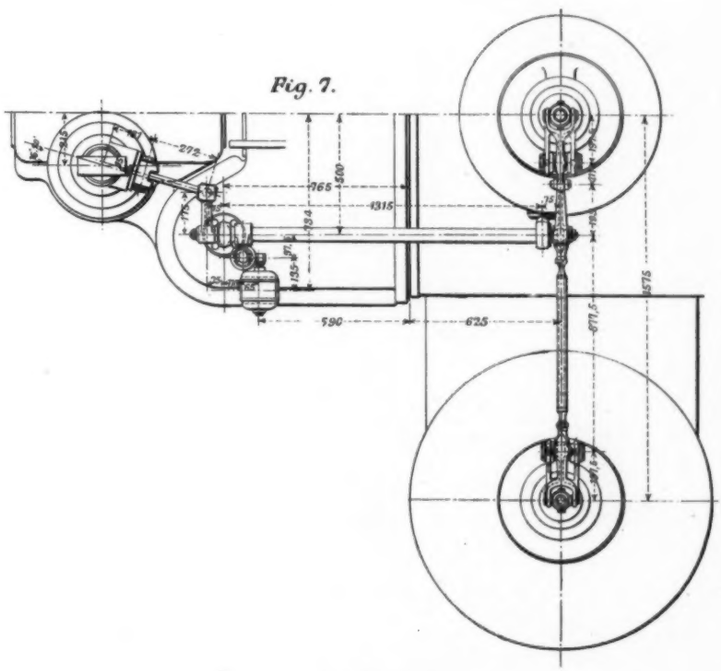

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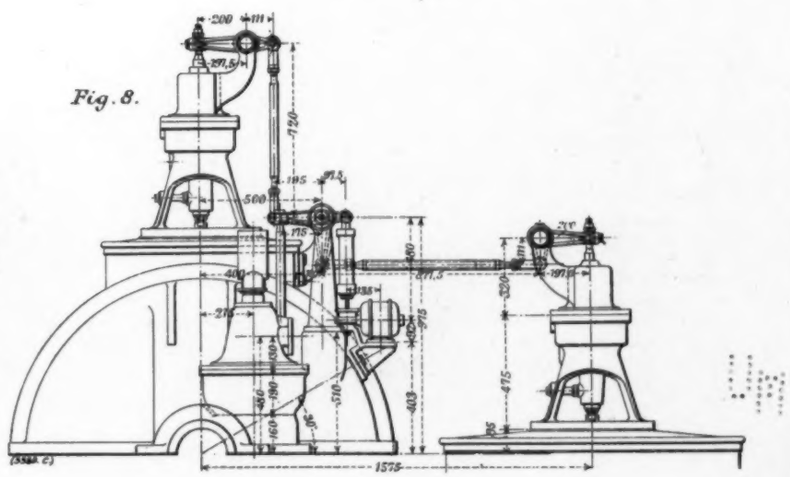

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Advertisements intended for insertion in the current week's issue must be delivered not later than 5 p.m. on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than Monday morning.

SUBSCRIPTIONS, HOME AND FOREIGN.

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Thin paper copies	£2 9 6
Thick ,, ,,	£2 14 0

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We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS "ENGINEERING," WESTRAND, LONDON.
TELEPHONE NUMBERS—8068 and 8598 GERRARD.

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With a Two-Page Plate of the LOW-PRESSURE STEAM TURBINES AT THE LARDERELLO NATURAL STEAM POWER STATION.

NOTICE.

Owing to the recent Government restrictions, and to the enormous increase in the price of paper occasioned thereby, the Proprietors of "ENGINEERING" are compelled to advance the price of this Journal further from 8d. to 9d. per copy. This increase dates from and includes the issue of Friday, March 1, 1918. The change will not apply to unexpired subscriptions. The revised rates for new subscriptions are given in the adjoining column.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper and the consequent shortage of supplies, Newsagents will not have copies for chance customers: therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 345.

ENGINEERING.

FRIDAY, SEPTEMBER 27, 1918.

AERONAUTICS.

In the years before the war the annual reports of the Advisory Committee on Aeronautics proved a veritable mine of authoritative information on both the practical and theoretical aspects of aerial navigation. This unrestrained publication of expensively acquired data naturally ceased with the outbreak of hostilities, and this year's report, which has just been issued, must be regarded merely as a statement of the policy adopted by the committee, since it is obviously impossible to publish results of elaborate experiments which would be exceedingly welcome to the common enemy. At the same time it is, of course, highly important that the fullest possible information should be at the service of those who build and design our aircraft, and the committee have accordingly arranged that confidential reports of progress shall be promptly and systematically communicated to the manufacturing firms concerned. Moreover, arrangements have been made by which representatives of private firms are invited to attend meetings of certain of the various sub-committees and give them the benefit of their experience.

It is, we may add, reassuring to note that the attempt to centralise all experiment and design in a single establishment, of which there were indications in the early period of the war, has been abandoned, if, indeed, the project ever existed outside of the minds of a few permanent officials. The loss by overlapping is commonly exaggerated, and indeed it is essential to progress that a certain amount of overlapping should exist. A second and independent observer may view the same experimental facts from a different angle and reap thereby a harvest, which another worker with his interests differently directed may have missed. That a number of independent bodies are engaged in aeronautical research is thus a positive advantage, whilst the fact that the committee visits these independent stations periodically and receives their technical reports and papers should ensure economy of effort. Of course, much will depend upon the spirit in which the services of this co-ordinating body are regarded. In the past it has been by no means infrequent for an officer charged with important investigations at the national expense to regard the results of his work very much as his personal property. The classical case is that of Sir George Murray, who treated in this way the surveys of Peninsular battle fields made by his department after the Peace of 1815. That this tradition is not yet dead was very evident during the earlier years of the war, as in many cases the engineers in the technical branch of the Air Services had the greatest difficulty in obtaining from officers appointed to carry out an investigation the actual results observed. If this spirit still exists, the Advisory Committee may find some difficulty in securing the due co-ordination of the work of the various research stations.

Our captures of German aircraft have made possible a very thorough comparison of the enemies' machines with our own. It is gratifying to learn that neither in performance nor in strength do the German aeroplanes stand on equality with the British, but are definitely inferior. Performance depends very much on the ratio of weight to power. This can be increased either by cutting down factors of safety or by skill in the design of both craft and engine. The Germans appear to have adopted the first and easier expedient, and the assertion of prisoners taken last spring that their machines were outclassed by ours is now definitely confirmed by the studies made under the direction of the Advisory Committee.

In this connection it may be added that lecturing at the recent British Scientific Products Exhibition, Dr. Rosenhain stated that an aluminium alloy taken from one of the many Zeppelins we have brought down proved to have a tensile strength of 25 tons per square inch. This was, he said, inferior to the corresponding alloy made here. This question of light alloys is obviously one of great importance, and the Advisory Committee accordingly formed a sub-committee for investigating these light alloys in 1916-17, most of the experimental work being carried out in the National Physical Laboratory.

Of course a satisfactory record in actual service constitutes the only really reliable guide as to the qualities of a new alloy. At one time it was thought that the so-called Wohler test could be counted on to discriminate between trustworthy and unreliable metals; but Dr. Stead showed some years since that certain phosphoric steels known to be unsatisfactory as structural materials, passed through most successfully the ordinary repeated stress test. Until experience has accumulated, however, guidance as to the value of a new alloy must be sought from laboratory experiments, and at Teddington these are very comprehensive and include experiments on the tensile strength at ordinary and at high temperatures, on the casting properties, and on the hardness, resistance to impact and to repeated stresses. Particulars would obviously be of the highest interest, but can of course not be supplied to the general public for a long time to come. Questions of strength are also occupying the attention of the Engine Sub-Committee. The modern aero-engine develops 400 h.p. on a total weight which twenty years ago would have been reckoned low for an internal-combustion engine of 10 h.p. or 20 h.p. This reduction in weights has necessarily involved the taking of some risks, as in the ultimate, the lightest engine will only be attained by letting it to some extent design itself. To this end parts may be pared away until failures occur, showing the danger line has been passed, and that certain steps must be retraced. The matter is complicated by the fact that materials are not always of unvarying quality, and the greatest vigilance is necessary in the shops to ensure that nothing but sound metal gets through.

Experimenting with full-sized machines is, of course, risky and expensive, though Mr. Handley Page has made great advances by his bold adventures. Generally, however, it is equally satisfactory, and much more rapid and less expensive, to try the experiments on small scale models. This course has been most successfully followed at the National Physical Laboratory where exhaustive experiments are made both with models of individual parts and of complete model aeroplanes. This course is necessary, as in such cases as this, the rule that two and two make four is more often honoured in the breach than in the observance. The air resistance of a component when built into a machine is, in fact, modified by the near neighbourhood of other parts.

Two new wind channels have been built at Teddington, one of which is to be used for measuring with the highest degree of precision possible the resistance of these models, which owing to the recent great increase made in the dimensions of large machines, have been steadily diminishing in relative scale if not in actual size. The comparison of a model with its prototype is in any case not as simple as might be desired, since the scale of relationship, so far as some of the most important

factors are concerned, is much less convenient than it is in the case of tank tests of ship models. In that case the greater part of the resistances are such that the corresponding speed of the model is considerably less than that of the ship. In aeroplane work, however, many of the resistances experienced are such as to have an entirely different relationship between corresponding speeds, a higher speed being required in the model than in the prototype. Since full sized planes are now attaining speeds of over 120 miles an hour; it is difficult to secure a strictly corresponding speed for the model experimented with. A sub-committee was appointed in 1917 to make a thorough study of these laws of comparison, and this committee has, it appears, succeeded in clearing up many difficulties, though perfectly general conclusions have not yet been reached. In this matter it appears that Teddington and the Royal Aircraft Factory have worked hand in hand. the model experiments made at Teddington being compared with the observations made on full-sized machines at Farnborough.

The theory of aeroplane stability was first worked out in this country by Professor G. H. Bryan, and though engineers quite properly resented his proposal at the Portsmouth meeting of the British Association that they should stop experimenting until he had completed his mathematical theory, the value of the latter is now universally admitted, and was most successfully employed to produce by rational methods the first inherently stable machines. These though the particular pattern is now, of course, far outclassed were in certain respects much in advance of their contemporaries built elsewhere. From the report of the advisory committee it appears that a grant was made to Professor Bryan during the year 1917 in order to enable him to prosecute further his investigations on aeroplane stability, and results of considerable interest have, it is said, been attained. New apparatus for determining the "rotary derivatives" which appear in Professor Bryan's equations has been installed at Teddington.

Much attention has been given during the year to propeller experiments. The number already made in this country and abroad is legion, but until recently the practical value of the observations made has been far from commensurate with the expenditure of cash and skill. No doubt so far as final results were concerned the theories of Rankine and Froude were satisfactory, but these did not deal in detail with the mutual reaction of the fluid and the blades. On the other hand the theory much in evidence of late by which an element of a propeller blade is assimilated to an aerofoil of similar section provides a much more definite picture of the interaction of fluid and screw. Possibly certain reservations as to the completeness of the analogy may eventually prove necessary, but the concept will certainly do much to guide experimenters in the path most likely to afford fruitful results, so that great progress in the rational design of propellers is likely to be effected in the near future.

The report states that owing to the insistent pressure of the times for immediate results, it has not been possible to conduct many of the investigations in progress in as continuous and as systematic a manner as is desirable. A rational and comprehensive scheme of research is no doubt that which in the long run is both the most fertile and the most economical, but long views are necessarily somewhat at a discount at present, since immediate difficulties by which construction is being held up must be dealt with out of hand, even at the cost of interrupting important systematic researches.

It will be seen from what we have said above that the report shows that much invaluable work is being done under the auspices of the committee. Full records have, of course, been secured, and the issues of the reports made in the years immediately following the re-establishment of peace, will probably be very bulky volumes.

OIL DEPOSITS OF THE MEXICAN GULF COAST, U.S.A.

THE discovery of oilfields in Texas and Louisiana belongs to this century, and the fields seem to be associated with the peculiar salt domes of these districts, the existence of which the drilling for oil has revealed. The flat, partly marshy ground of the Gulf Coast gives little indication of the salt domes. Sometimes the hidden salt domes are under distinct hills up to 100 ft. high; as a rule the structureless Pleistocene overlying the oil-bearing rocks gives the geologist no clue, and drilling was started because gas seeps, "paraffin-dirt," exudations of oil or asphalt, or sulphur and salt springs and mud springs attracted the attention of prospectors. An extraordinarily rich oil well was discovered on the Spindletop dome, Texas, in 1901, and a new oil industry rapidly developed on the Gulf Coast, in which enormous capital has been invested, and thousands of workers are now engaged. In most cases, however, the abundant flow was not long maintained. Some wells seemed to become exhausted in the course of days or weeks; there might follow a second period of rich yield; but hundreds of dry holes are drilled each year at present in fruitless blind efforts to discover new fields, the new wells drain the old ones, and the actual total oil production of the Gulf Coast is not supposed to exceed that of 1906. The outlook is not satisfactory, and it is clearly time to adopt scientific and systematic methods of prospecting. The problems have been much discussed of late, especially also by the American Institute of Mining Engineers. This body was again to deal with the matter in connection with a paper by Mr. Anthony F. Lucas on "The Possible Existence of Deep-seated Oil Deposits on the Gulf Coast," to be read before the September meeting of the Institute at Colorado; the paper was published in the Bulletin of the Institute of July, 1918. Geologists are by no means agreed as to the origin of the salt domes and of the oil in them. One may incline to the view advocated by Lucas, however, that all the salt-dome oil has a common origin, having migrated up from considerable depths along lines of structural weakness, and that it should be tapped at great depths. Evidence is, moreover, adduced that there is oil all along the coasts of the Gulf of Mexico and under the Gulf itself.

The Gulf of Mexico forms a vast basin, roughly 2,000 km. long east to west and 1,000 km. wide north to east. We may, indeed, think in this connection also of the still vaster basin of the Caribbean Sea, which is joined to the Gulf of Mexico; for there is oil and bitumen in Trinidad, Venezuela, the West Indian Islands, and Central America, as well as in the Antilles, Cuba, Puerto Rico, &c., which separate the two seas. In 1910, Lieutenant J. C. Soley, U.S.N., drew attention to the fact that there were oil shoals (Ship and Trinity Shoals, *e.g.*) not only near the shores of Louisiana, but much further out in the open Gulf where the depth is over 1,000 fathoms, and even in Sigsbee Deep, north of Campeche Bay, within the 2,000 fathoms line. Cakes of sea wax, 8 ft. long, 2 in. thick, are found near Sabine (Texas) and Matagorda (Mexico); once public interest had been aroused, it became known that ships not infrequently passed through oil pools in the Gulf and met with turbid and milky water in its eastern portions where oil itself was not observed.

Where that oil comes from is purely conjectural, of course. A little more is known about the salt domes which seem to be connected with the occurrences of oil and natural gas in Texas and Louisiana. About 60 of these domes are known; 20 or 30 of them are associated with commercial oilfields; a dozen of these have become important, the others have yielded a puff of gas or a little oil, but have proved failures. It would appear that these domes are masses of fairly pure rock salt, generally flat-topped and overlain by surface strata, from 25 ft. to several hundred feet in thickness, of limestone, dolomite, gypsum, anhydrite and sulphur; but any of these materials may be missing. The flat top may have an area of several square miles and diameters ranging from ½ mile up to 1½ miles. From the flat top the salt slopes abruptly at various angles, and the oil and gas may be found in the salt itself, or more frequently in the sediments above (the cap rocks) or in the slopes. The gas pressure is often very high; the Spindletop machinery, on which Lucas worked in 1901, was wrecked by the gas; disastrous blow-outs have occurred at Humble and elsewhere, and at Belle Isle pressures of more than 1,000 lb. per square inch were recorded. At Terrebonne, near the latter place, high-pressure gas is so abundant that a pipe line is to be laid to New Orleans; in that case, there is no salt dome, but the gas supply promises to be fairly lasting, whilst in many other cases the rapid diminution of the yield suggests pocket occurrences of gas and oil. The salt brought up with the bailers at Belle Isle contains visible enclosures of oil and gas; dumped on the derrick floor, this salt jumps and flies to pieces like poppcorn, leaving the floor covered with oil and paraffin; during a cold spell the slush pond was covered by an inch of solid paraffin.

From the general character of the phenomena and the frequent occurrences of sulphur in and near the salt, Lucas concludes that the domes were forced upward by igneous rocks rising from below, and that the sulphur bears evidence to vulcanism and solfatara action. But J. A. Udden—to mention one objection only—points out in the same journal that neither the igneous theory, nor the "squeeze" theory accounts for the character of the cap rock and the extensive sulphur deposits in it. The upward circulation in the domes of liquid and gas, first proposed by R. T. Hill and G. D. Harris, may better fit the phenomena. Geologists hardly have sufficient data to work upon, however, and they will welcome the suggestion of systematic deep borings. Wildcat schemes have prospered less here probably than they have in America; but our geologists have had reason to complain about injudicious boring and non-publication of the results. At Belle Isle the colour of the oil changed from yellow to reddish at a depth of 3,171 ft., when the casing collapsed, and operations had to be abandoned. That was not a great depth, of course. In some wells of the districts, depths of 4,000 ft. and 5,000 ft. have been exceeded; the Hope National Gas Company had, last February, penetrated to a depth of 7,363 ft. in West Virginia, and with modern machinery such depths are feasible. Systematic drillings, supervised by expert geologists, promises better success probably than prospecting for salt domes with the aid of novel devices, gravity balances or magnetic dipping needles, though such devices and the analytical differences between the ordinary ground water and the water from oilfields (G. S. Rogers) may afford valuable help.

THE SHIPBUILDING SITUATION.

THE recent statement on the merchant shipbuilding situation by Lord Pirrie, the Controller-General of Merchant Shipbuilding, was of very great interest as a statement of the present position of affairs, but it was also noteworthy in that it stated clearly that the First Lord of the Admiralty, Sir Eric Geddes, had definitely promised to release a number of the workers at present employed on warship construction for service in the construction of merchant ships. In his speech on the Navy Estimates in July of this year Sir Eric Geddes pointed out that upon this country had fallen almost exclusively the task of meeting and defeating the submarine peril, with the result that a very large proportion of the shipyard labour of the country was exclusively employed upon the construction of vessels for this service. Sir Eric Geddes further pointed out that as the American programme of anti-submarine construction materialised the situation as regards this form of shipbuilding effort in our yards would be eased and the labour would thus become available for replacing our own merchant ship losses. That this satisfactory condition of affairs has now been reached is a natural inference from the statement of Lord Pirrie, and it is to be hoped that the transfer of workers will take place at the earliest possible moment.

It is to be noted that among the shipyards which will be affected by the reduction of naval construction are some of the largest and most important in the country, and the class of labour employed in them contains a higher proportion of highly-skilled men than is usual in yards building cargo vessels exclusively. The yards affected are largely equipped, and the staff and other workers organised, for the rapid production of the highest class of merchant tonnage rather than purely cargo vessels, and it therefore becomes a question of importance whether

the machinery and man-power now becoming available would be more usefully employed in producing standard cargo vessels or in replacing a number of the larger vessels of the liner type of which so many have been lost during the war. Of the number of such vessels lost no record is available, but the large number of important ships of which the loss has been officially reported points with certainty to the fact that after the war there will be a very serious shortage of this class of vessel. In view of the intense competition which is certain to follow the cessation of hostilities and the severe handicap under which British shipping companies will of necessity be placed owing to the loss of so many of their ships, it is worth while considering whether the construction of a number of such vessels, predicted in July by Sir Eric Geddes, could not now be sanctioned. The fact that the plant and machinery now becoming available would be working on its normal quality of product and therefore presumably at its maximum efficiency is a point to be borne in mind in deciding its sphere of greatest usefulness. It is neither desirable nor necessary that such vessels if constructed should be fitted out for their post-war trade until the end of the war, where such fitting-out involves elaborate passenger accommodation, &c., but the urgent need for vessels of the liner type will be at once admitted.

Another class for which there will be an urgent demand and for the construction of which a high degree of skill is required is that of the high-speed cross-Channel steamer. Most of those which survive war service will be quite unfit to resume their normal duties and their replacement will be an urgent necessity as traffic across Channel will be very heavy. This type of vessel is also very largely the product of the shipyards and labour which produces the liner class of vessel and is therefore suitable for construction by the plant and labour now to be set free from naval work.

The ultimate decision as to the types of vessel most urgently required and consequently the work upon which the extra building facilities will be employed must, of course, be dependent upon facts known only to the shipping authorities, but it is to be hoped that in making their decision due weight will be given to the need for the replacing of special types of merchant vessel and to the most efficient use of the facilities available.

LIQUID CRYSTALS.

EVIDENCE has been accumulating during the last few decades that there is justification for speaking of "liquid crystals." The term certainly does not appear to accord with the time-honoured distinction of the three states of aggregation, the solid, liquid, gaseous. Nor do bodies like pitch and wax and others which gradually soften without having a definite melting-point exactly fit into this classification. But crystals, substances, which in solidifying assume definite, though varying shapes with straight edges and plane faces, and which are characterised by peculiar optical and other physical properties not found in either amorphous or in liquid substances, seem to be the solids *par excellence*, and it is difficult to imagine such substances to partake simultaneously of the characteristic properties of solids and of liquids. Yet we know now a large number of crystal-like bodies of more or less constant shapes, which unite when they meet, forming twins which may split again, which may be distorted into spirals, and which not only possess some of the specific properties of crystals to an enhanced degree, but actually display certain optical properties for which scientists have so far been looking in vain in solid crystals. These liquid crystals may drift in a trough across which wires have been stretched and float right through the wires to close up again and to reassume their original shape and properties, very much like the proverbial ghost floats through the walls and is left unharmed by bullets and sword thrusts. These liquid crystals are real, though they are best studied under the microscope and polariscope.

The term "liquid" crystals was introduced in 1888 by Professor Otto Lehmann, of Karlsruhe, who remains their chief investigator. He was soon joined by an ardent but critical small group of workers, and the optical side of the phenomena and their theoretical bearing in particular have been much discussed. Demonstrations of the beautiful colour effects of liquid crystals observed in polarised light have been repeatedly given over here, and it is they which first attracted wide attention. In most of these experiments some of the original solid substance is placed on the microscope stage between two glass plates (one of which may be a lens) to form a layer about 1 mm. in thickness which is heated from below. Examining cholesterin benzoate in this way in 1888, Reinitzer observed that the liquid existed in two phases, the one melting from the solid at 145 deg. C., the other forming at 179 deg. The former turbid phase proved doubly refractive; at one spot a deep violet colour shot up which spread all over the liquid to vanish again; on further heating the violet reappeared, the liquid cleared, and solidified on the cooler portions of the glass to colourless crystals. The two phases were reversible. When the heating of the stage is central, the hottest liquid above the flame is generally isotropic, the cooler layer surrounding this central liquid is anisotropic (doubly refracting), and the solid crystals settling further outside have their own properties; we will presently explain the terms briefly. A normally anisotropic liquid was not known at the time; for this and other reasons Lehmann, who was engaged in similar researches, proposed the name "liquid crystals"; others preferred to speak merely of anisotropic liquids. More liquid crystals were found; Gattermann prepared the *p*-azoxyanisol and the *p*-azoxyphenetol, which have become famous in these researches, and D. Vorländer succeeded in preparing 170 new organic compounds of widely different types and constitutions which had the desired peculiarities. More have been added to the list since.

All homogeneous liquids are isotropic like amorphous bodies, glass and crystals of the regular system, that is to say, they propagate light, electricity, and stresses equally in all directions without showing any preference for any direction—unless they be strained mechanically or thermally (the case of rapid cooling of glass), or by magnetic or electric fields. They then turn anisotropic; that is, there are preferential directions for the propagation of light, &c., and these directions are connected with the one or more optical axes of crystallisation or with the lines of stress. In the quadratic and hexagonal systems the one optical axis is the crystallographic axis which is longer or shorter than the other two or three axes, and any ray not parallel to that axis is split into two rays, which are polarised at right angles to one another. Owing to interference or to circular polarisation beautiful colours appear at the same time when the observations are made between Nicol prisms, and as the absorption of light is likewise different in different directions, the colours may also change with the direction (dichroism).

Many of those features now are observed in perplexing complexity in liquid crystals, and it seems difficult in particular to conceive liquid crystals on the modern view that the atoms of a crystal are arranged in definite positions in a rigid space lattice. Such difficulties were not novel to Lehmann, however. He had found five modifications in the solid crystals of ammonium nitrate, having transition temperatures lying between − 16 deg. and + 125 deg. C.; he had bent these crystals to rings without changing their transparency or solubility; silver iodide, he had observed, exists between 146 deg. and 450 deg. C. in a viscous mass, yet in regular crystals; it was known that rock salt crystals are easily bent by small loads and remain permanently deformed (W. Voigt). Moreover, small crystalline particles are believed to slip over one another under stress. The rigid space lattice did not then appear to be essential to crystallisation. Many of Lehmann's liquid crystals do not look like crystals. They may be slimy spherical drops, threads, conical, doubly conical (like two tops placed with their bases in contact); or they may appear decidedly polyhedric in shape like real crystals, or ribbon-like splitting into their constituent parallel rods, &c. Even the simple spherical drops, however, show an axial spindle which by preference places itself at right angles to the glass. Two diamond-shaped crystals may unite to a Y, the two wings of which flap together the next moment, perhaps to separate again. The already-mentioned experiments of cutting up the crystals by letting them drift against wires was made with ammonium-oleate hydrate. Air bubbles, dye particles suspended in the fluid, and portions of the solvent take up regular symmetrical positions in the crystals, or between them, as if they formed part of the crystal structure.

Let us briefly examine the different properties and the suggestions made for their explanation. The first objection raised against liquid crystals was that the crystal floating in its solvent or in its own melt was not pure, but contaminated with solvent or impurities. That objection was met by preparing the pure substance and contaminating it purposely; the phenomena remained substantially the same. The individual character of the crystals is little disturbed by heat, except that the drops begin to rotate, especially when lying flat on the glass stage—why, is not clear, but there is a strong general tendency to rotation. When a drop is flattened out, it changes its structure; a divided drop gives two halves of the original shape. In the magnetic field the crystals or axes place themselves parallel to the lines of force, mostly in the same direction, sometimes in the opposite direction (C. Mauguin). When the impurity hypothesis broke down, an arrangement in homogeneous layers was proposed. The rotation phenomena and other facts, also that particles of the solid phase adhering to the glass seemed to serve as nuclei for the subsequent crystallisation and other influences of the glass plates seemed to support that view; but the behaviour of the liquid crystals between mica (instead of glass) plates was altogether peculiar. Further, if the liquids were suspensions or emulsions of the one phase in the other, or in the solvent, the clearing of the turbidity should be gradual, whilst it is sudden, and capillary experiments on the internal friction and experiments on the dielectric constants of the two phases fail to support that assumption. The swarm-hypothesis, a special case of the emulsion hypothesis, did not prove satisfactory either (E. Bose, W. Nernst). Finally, S. van der Lingen, submitting liquid crystals to X-ray examination, did not discover any evidence of a space-lattice structure.

Some of the optical phenomena are exceedingly curious. The azoxyphenetol shows between crossed Nicols the dark cross of optically active crystals (circular polarisation) and alternately white and yellow tones in the quadrants. This appearance is not changed when either the polariser or the analyser is removed, except that the quadrants change places. There is hence rotation of the plane of polarisation. Whilst, however, a quartz plate of 1 mm. thickness would call forth a rotation of about 25 deg., these rotations were much greater; anisal cinnamonic acid gave rotations of 4,000 deg., a cyanogen compound of this body even 12,000 deg. Investigating these peculiarities together with F. Stumpf, Woldemar Voigt, of Göttingen—an authority on crystallography and optics—partly with the aid of a novel Newton-ring apparatus which can be turned about its vertical axis while under oblique illumination, obtained evidence of quite extraordinary intense absorption and dichroism, and he observed phenomena—as we stated in the introduction—long looked for, but not so far been realised with solid crystals. These Voigt explains by suggesting a zone of missing double refraction, in other words, a cone of optical axes in these crystals, the possibility of whose existence had long been recognised. Thus some difficulties seem to have been solved, others await solution. We should add that Svedberg, of Upsala, who investigated the electric conductivity of liquid crystals, has recently taken up the theoretical studies together with C. Bergholm, Y. Björnstahl, and others. An atlas of the brilliant colour phenomena was published some years ago by Hanswaldt.

If we sum up we may say that a *prima facie* case for the existence of liquid crystals seems to have been made out. The analogies between anisotropic liquids and real crystals certainly go far. The molecules of certain classes of liquids are capable of assuming definite shapes, which they retain and

reassume when disturbed, and of arranging themselves in directions parallel to their axes; there is little evidence of orientation normally to that axis. Whether they could be fitted into a space lattice is uncertain. Optically they behave like uniaxial crystals, and it is noteworthy that certain peculiar phenomena as to double refraction and colour which theory had predicted for crystals have never been observed yet, except in those liquid crystals, and that other phenomena appear much more striking in them than in solid crystals. The liquid crystals are affected by magnetic and electric fields, and show a preferential electric conductivity like crystals. The action of heat is far less disturbing than in the case of gases. But the phenomena seem to be limited to certain temperature ranges. Outside these limits there must hence be molecular or atomic rearrangements or constitutional changes, the nature of which is unknown; thermodynamically the phenomena seem to be explicable. To account for the analogies W. Voigt suggests that the bricks of solid crystals are the atoms, and that the bricks of liquid crystals are the molecules. Regular molecular aggregates may have different properties from atomic aggregates. The atomic, as distinct from the molecular, structure of crystals would be in accordance with the results of the investigation of the solid crystal structure by X-rays. The atoms of crystals are held together by the same strong polar forces of enormous intensity at small distances which bind the atoms to chemical compounds. The cohesive forces, which keep the molecules of real crystals together and decide their definite shapes, are weak in anisotropic liquids; hence the individual masses may appear in spherical, conical or polyhedric shapes, according to their consistency. In that continuity of form Voigt still sees evidence of a difference in principle between solid and liquid crystals. Lehmann does not accept that distinction of atomic and molecular bricks. He ascribes to the solid crystals a definite limit of elasticity which the liquid crystals do not possess. Going beyond the atom and molecule M. Born has attempted to extend the theory of fixed dipoles to anisotropic liquids, and electrons have, of course, been called into requisition. There remains the fundamental objection, originally raised against the suggestion of liquid crystals, that the complex organic compound in question may be partially decomposed and hence heterogeneous. But the provisional acceptance of "liquid crystals" will not impede the further investigation of these problems.

We feel tempted to conclude with two plain questions: Can we conceive the ultimate particles of fluids to be anything but solid? And must not regular arrangement of the atoms or molecules precede solidification in crystallisation?

NOTES.

Giant Aeroplanes.

It is now just 10 years since Wilbur Wright demonstrated man's conquest of the air by his flight of 30 miles in forty minutes. At Rheims one year later, the carrying of three passengers was thought a wonderful feat. The extent of the progress since made was strikingly demonstrated by the machines on view at the works of Messrs. Handley Page, last Monday. It is, of course, impossible for the present to give particulars of the dimensions of these monsters, which in the opinion of their designer are likely to prove as useful in peace as they are effective in war. Mr. Page declared that passenger transport by aeroplane promises to undergo a most remarkable development. With guaranteed full loads at first-class fares he said that the undertaking would return a profit of 98 per cent., though whether in arriving at this figure an allowance was made for the cost of aerodromes was not definitely stated. Certainly he showed by the most convincing of all proofs, actual trial, that the passengers would have (apart from the roar of the engines) little to complain of as regards their comfort, whilst as to their security he exhibited a most reassuring photograph which demonstrated most strikingly the high margin of safety characteristic of these machines. The photograph in question showed the plight of a machine near which a German high explosive shell had burst. The effect was practically to strip the lower plane of its canvas, yet with the shreds hanging from the frame in festoons this machine flew 60 miles to the safety of its own lines. The endurance of these machines also appears to be high, since Mr. Page stated that one delivered in 1916 was still flying up to two months ago, its last flight being one of 500 miles.

The Post-War Position of Electric Power Supply.

The two reports on Electric Power Production have prepared the public mind for the creation of a number of super-power stations as soon as the more important demands for munitions have been satisfied and engineers can apply themselves to the production of the necessary machinery. Nothing can be more advantageous to the reorganisation of the country on a peace basis than a plentiful and cheap supply of power in all our towns and villages. But many people have formed an exaggerated idea of the cheapness at which electric energy can be delivered from large turbo-generators and enormous stations; and Mr. Ernest Hatton was well advised, in his presidential address before the Municipal Tramways Association Conference yesterday, to utter words of caution against the popular idea that electricity can be supplied for nothing, or next to nothing. That large stations, situated in suitable localities can turn out energy at low figures is certainly true, or rather it was true before the war. But the figures quoted have usually been the cost of energy at the switchboard, and not at the terminals of the consumers' motors. It is remarkable that although electricity is invisible and imponderable it is very costly to transmit over long distances. Time and again it has been shown that it is cheaper to carry coal by rail to the generating station than to place the plant at the pit-head, and carry the current by wires over long distances. Distribution adds much to the original cost, and if it entails two or more transformations these have also to be paid for. The new stations will be built with dear materials and dear labour, and the capital charges will be high. Generally the distribution will be in the hands of municipalities, who must add to the price the capital charges resulting from the sacrifice of their existing plant. Mr. Hatton said: "Any scheme of general power supply, if it is to be a success must, within a reasonable period, by its more economical working and production on a large scale, be able to carry on its back the annual charges upon the plant which will be superseded or closed down by its adoption." In the smaller towns this burden will often be serious, for it is well known that the plants have often not been written down as they should have been. There is plenty of obsolete machinery that will never go round again, but which is kept in the stations so that it may figure as an asset in the balance-sheet. Sometimes the business has not brought in sufficient returns to allow of drastic writings-off, and sometimes the money has been unwisely used in the reduction of the rates. Whatever be the reason, interest and amortisation have still to be paid, and unless the burden be placed directly on the ratepayers it must be carried by the new concerns. They will be much in the position of the electric traction companies who bought out the horse tramways, paying long prices for "two streaks of rust and a right of way." This was generally the case with the private companies; the municipalities often obtained their local lines at the "then" value, which was very small. However, if the electric supply should cost more than many expect, it will only resemble other things in this respect. The purchasing value of money has fallen immensely, and it will take many years of peace to re-establish it on the old footing, if indeed that end is ever attained, which is very problematical.

The British Scientific Products Exhibition.

The British Scientific Products Exhibition, which was closed on September 7 after a very successful career of four weeks, has, in an eminent degree, brought home to many people, of the technical classes as well as of the general public, what the proper co-operation of scientific and technical knowledge and skill can accomplish. A very large proportion of the products, wares and apparatus exhibited at King's College were not manufactured, and could not have been manufactured, in this country before the war, and in a good many other cases the firms had not themselves manufactured the articles which they showed together with other goods of their own. The public has been told this almost *ad nauseam*. They began to realise it when goods, which they could no longer buy after the available stocks had been exhausted, made their reappearance on the market, not always of satisfactory quality, and the Exhibition has taught them how that has been made possible. To acknowledge those facts does not mean to forget or to deny that this country excelled in many lines. But matters had been going on too smoothly. Branches of manufacture which did not promise substantial direct profits were left to the competition of foreigners, who did not mind years of hard work without immediate return and who were willing to risk heavy expense in the sure conviction that all systematic scientific study must in the end benefit mankind, and would probably bring its own reward. The inevitable result was that the home country became in many fields dependent upon foreign supply to a deplorable degree, and that the industry of the country was pushed out of some fields in which it had held a commanding position. For it is, after all, quite justifiable to speak of the industry of a country in the singular; the many industrial branches are so closely inter-related and interlocked, that no link in the chain must be allowed to rust. That is what individuals engaged and interested in their own particular business were prone to forget, and the Government had not the insight and foresight to guide them and to educate the masses to a proper understanding. It required the catastrophe of the world's war to rouse the people out of their easy-going lethargy, and it required exhibitions like the one arranged by the British Science Guild to make the public understand what proper organisation and systematic scientific methods can accomplish. There is danger that, with the relaxation of the terrible strain of a many years' war, industry will drift back into its old grooves, too proud of having been able—in a measure which must not be overrated—to make up in a few years for decades of placid ease, nursing the hatred of the enemy, but not nursing the spirit of research and of industrial application to which he owes his success. The visitors to the British Scientific Products Exhibition should bear that in mind. There was nothing to attract the sightseer; the shop element was barred; people went to learn. The organising committee would have liked to assist the visitors more in that respect than circumstances—the impossibility of sparing competent representatives of the firms in the first instance—permitted them to do. The signal success of the Exhibition is all the more pleasing. We are in a position to state that the cost of the Exhibition, calculated on the 30,000 visitors who attended, works out at about 2*s.* 6*d.* per head. It will be understood that the members of the committee regarded their manifold arduous duties as strictly honorary. Perhaps we may single out a few names of members of the committees to whose untiring efforts credit is chiefly due. In our series of articles we mentioned only the president and the secretary of the organising committee, Professor R. A. Gregory and Mr. F. B. Spiers. Sir Robert Hadfield—Sir Robert is President of the Faraday Society, of which Mr. Spiers has been Secretary from its foundation—must also be mentioned in this connection, together with Colonel Sir John C. Young, who looked after the finances, and Colonel O'Meara, R.E., the secretary of the British Science Guild. The Guild contemplates, we believe, another Exhibition at an early date.

Machine Tool and Woodworking Machinery Release Certificates.—As from September 16, 1918, all applications for permission to purchase machine tools for woodworking machinery must be made to the Machine Tool Department (T.M. 7), Charing Cross Buildings, Embankment, London, W.C. 2, instead of to the Area Clearing House Boards, as hitherto. Applications must be made upon Form "A" which may be obtained from the Machine Tool Department or from the various area offices of the Ministry.

LITERATURE.

Heating and Ventilation. By JOHN R. ALLEN, Dean of the Department of Engineering and Architecture, University of Minnesota, and J. H. WALKER, Superintendent of Central Heating, the Detroit Edison Co. London: Hill Publishing Co., Limited. [Price 15*s.* net.]

AT a time when the drastic action of the Coal Controller threatens a diminution of creature comforts, and the open fire may prove a luxury that will invite the attention of another class of Government economists, Messrs. Allen & Walker unite in describing the processes of heating and ventilation in the United States, where a fiercer degree of cold than we experience has led to the use of more scientific and more economic methods than generally find favour here. We are content if we can maintain in our residences an average temperature of from 55 to 60 deg. F., but in America the winter temperature of the domicile ordinarily ranges from 65 to 70 deg. F. The temperature is maintained in spite of the greater difference observable between the inside and outside atmospheric conditions. In New York City, it is customary in making heating arrangements to provide for an outside temperature of zero Fahrenheit, and in Saint Paul for one 20 deg. lower, such inclement weather being expected to continue for at least a period of 24 hours. One may expect therefore, that the methods of internal heating have been very carefully considered, and that for our extravagant and primitive plan of open fires, more thorough and efficient methods have been substituted. This treatise, detailing the latest methods for practice and the theoretical principles that have guided experts, is evidence of the progress and success that have been attained. There is no opportunity of presenting much that is new, for the problem of domestic heating does not offer startling possibilities, but in the orderly presentation of facts, we are reminded of many things that have been neglected or treated with indifference. In this collection of accumulated experience, there is much that will be of assistance to engineers and architects, and at the same time prove a useful guide to the student.

We have been told many times and the authors repeat the accusation, though to deaf and unwilling ears, that our prized open fire is a very uneconomical form of heating. In the best constructed open grates it is to be feared that not more than 20 per cent of the fuel consumed is effective. Against this charge we can only plead, as indeed the authors admit, that the feeling of a grate-heated room is quite different from that of a room heated by other means. The American method is to warm the air of a room: ours, to warm the objects in it. Radiated heat, and with the open fire we rely entirely on radiation, does not heat the air through which it passes. As a consequence, the capacity for moisture is not increased as much as it would be if the air were heated to a higher temperature, and the presence of a proportionately greater amount of free moisture in the air is appreciated, though the reason for the agreeable sensation is not so generally apprehended.

On grounds of efficiency, the stove is preferable, and in the coming winter many may wish that they had installed this form of heating apparatus in which some 70 or 80 per cent. of the fuel is utilised. Radiation and convection are both operative in increasing the temperature, an obvious advantage, but objections to this form are raised on account of the space occupied, the unsightly appearance, the attention required, and with more reason, the failure to provide effective ventilation. The alternative, and the natural outgrowth to the stove is the hot-air furnace, in whose favour it is argued that it does not interfere with the habitable portion of the house, that it provides a cheap method of both heating and ventilation, requires little attention, and with proper care does not deteriorate. On the other hand, the apparatus is seldom dust-tight; dust, ashes and gases from the fire are carried into the rooms, and it is a further disadvantage that the circulation depends upon natural draught, that is, on the small difference in weight between the air inside and outside the flues. On account of the small available force it is recommended that the length of the horizontal flue should not exceed 15 ft.; a very necessary precaution.

Direct steam heating is an alternative that is adequately discussed, but this system, if not supplemented by some efficient means of ventilation is not considered an improvement on the hot-air furnace. It possesses many advantages, for example, a distant room can be heated as easily as one close to the boiler, but if the radiators, as usual, are designed to be sufficient on the coldest days, the room may be overheated at other times, without careful attention is given to the manipulation of the valves. The objection has led to many variations in design in order that steam may be used at atmospheric pressure or even below, making regulation easy, since the steam supply to each radiator can be controlled at the inlet valve.

Direct heating by water circulation possesses many of the advantages claimed for low pressure steam, but as the temperature of the water is less, a greater radiating surface is required. Such an arrangement gives off more heat by convection and less by radiation, and this combination results in the maintenance of a fairly equable room temperature, satisfactory to the occupants. The circulation of the system is, however, limited by the condition that the action depends on the difference in weight of water in the hot and cold leg of the installation, generally not more than 10 or 20 deg., and the friction in the pipes and other physical causes may occasion trouble, only to be remedied by the introduction of a pump.

In indirect systems the heating surfaces are placed outside the rooms to be heated, and air passing over these sources of heat flows to the various rooms through pipes or flues. The principles governing the introduction of air do not differ from those employed in the installation of the hot-air furnace, and the main advantage of such a system consists in the exclusion of dust and obnoxious gases, while each room, having a separate source of heat, can be regulated to a temperature that suits the inmates. But whether the system adopted is direct or indirect, it is impossible to introduce sufficient quantities of air to make ventilation satisfactory when large numbers of people are collected in a limited space. Some mechanical means must then be employed to supply air. The fan provides the necessary device. With this contrivance the air is taken from the outside, or sometimes recirculated from the buildings itself, passed through the heating coils, when necessary, and forced into the building.

The object of the authors is to describe these different systems, to show the modifications that may be necessary under certain conditions, and to indicate the proper mechanical contrivances for meeting all requirements. The mechanical apparatus is described and illustrated very fully, and in addition calculations are made of the amount of heat and the extent of radiating surface necessary to maintain a definite temperature These calculations are not simple, and at best can only be approximations. Reliance on experience has to supply the place of theoretical deductions, and fortunately there is a controlling factor which comes to the assistance of the hot water engineer. All ordinary hot water systems, though they be installed without any exact design, are to a great extent self-regulating. From the purely theoretical point of view the pipes may be too large or too small, the resistance in some circuits may be much greater than in others, but it is easy to follow some rough rule which will give pipe sizes on the safe side, and produce entirely acceptable results.

It must not be supposed from this remark that the work is either superfluous or tedious. The greater the tendency to trust to empiricism the greater the need for occasional examination of first principles, in order to determine the trustworthiness of received formulas. Moreover, opportunities for improvement are indicated which could not be suggested by the mere repetition of previous and imperfect results. More economic and more efficient command can be maintained when well determined principles have dictated the design and guided the installation. As an example, may be instanced the introduction of an automatic control to boiler or furnace, a check that contributes to both economy of fuel and personal comfort. In trusting to manual control there is always the possibility for the room to become overheated through lack of attention to radiator valves, and consequent waste of fuel, whereas by inserting some form of automatic thermostat, the temperature of a room can be kept constant at a point the most comfortable for the inmates without any manipulation of these valves. Or again, if adequate ventilation is proposed by means of a fan system, it is most desirable that the size of the ducts be intelligently selected, and the pressure loss in the system computed as correctly as possible. Data of approximate accuracy must be collected in order to ensure the selection of a fan having the proper characteristics. If the requisite quantity of air is to be delivered, the working head must be sufficient to overcome the resistance of the system. If, too, the various branches are not properly proportioned, air in correct quantities cannot be distributed to the various rooms. Something more than a rule of thumb is needed if the work is to proceed with certainty and confidence. Thermostatic control can be brought in here again to correct variations, but there is a limit to the work that can be put upon the regulating valves. Plenty of opportunities occur where the advice and information supplied by such trained guides as the authors will be of advantage to the inexperienced, and that the authors regard themselves as teachers is shown by the number of numerical examples attached to each chapter, to which they evidently expect the student to give attention. Many very useful tables are scattered through the text and extensions of some of these are collected in an appendix. The treatise is well indexed and well illustrated.

BOOKS RECEIVED.

Coal and Its Scientific Uses. By WILLIAM A. BONE, D.Sc., Ph.D., F.R.S. London: Longmans Green and Co. [Price 21*s.* net.]

How to Drive a Motor Car: A Key to the Subtleties of Motoring. Written and illustrated by the Staff of *The Motor*. Sixth edition. London: Temple Press, Limited. [Price 2*s.* net.]

University of Illinois Bulletin: Water Survey Series, No. 14, *Chemical and Biological Survey of the Waters of Illinois*. EDWARD BARTON, Director, Urbana. Published by the University of Illinois. [Price 1 dol.]

University of Illinois Bulletin, Engineering Experiment Station, Bulletin No. 103: *An Investigation of Twist Drills*. By BRUCE W. BENEDICT and W. PENN LUKENS. Urbana: Published by the University of Illinois. London: Chapman and Hall, Limited. [Price 60 cents.]

Selwyn's Metric Conversion Tables. Edited by W. ERSKINE DOMMETT, A.F.Ae.S., M.I.Mar.E. London: James Selwyn and Co., Limited. [Price 2*s.* 6*d.* net.]

The Institution of Railway Signal Engineers (Incorporated) for the Advancement of the Science of Railway Signalling. Proceedings; Session, 1917. Manchester: H. Rawson and Co., 16, New Brown-street.

Do You Pay Excess Profits Duty? By T. FRAME MILLER, F.C.A. London: George Allen and Unwin, Limited. [Price 1*s.* net.]

The Universal Directory of Railway Officials, 1918. Compiled from official sources under the direction of S. R. BLUNDSTONE, editor of *The Railway Engineer*. London: The Directory Publishing Company, Limited. [Price 15*s.*]

Ingots and Ingot Moulds. By ARTHUR W. BREARLEY and HARRY BREARLEY. London: Longmans, Green and Co. [Price 16*s.* net.]

Handbook of Mathematics for Engineers. By EDWARD V. HUNTINGDON, Ph.D. London: Hill Publishing Company, Limited. [Price 7*s.* 6*d.* net.]

Metals and Alloys, Tables containing the Percentage composition and other particulars of over 500 Metals and Alloys. London: Published by *The Metal Industry*, 35, Bedford-street, W.C.2. [Price 5*s.* net.]

Selected Papers on Social and Economic Questions. By BENJAMIN CHAPMAN BROWNE, *Knight*, Hon. D.C.L., Durham University. Edited by his daughters, E. M. B. and H. M. B. Cambridge: The University Press.

United States Bureau of Mines. Technical Papers. No. 141. *Laboratory Determination of the Explosibility of Coal Dust and Air Mixtures.* By J. K. CLEMENT and J. N. LAWRENCE. [Price 10 cents.] No. 147. *Absorption of Methane and other Gases by Coal.* By S. H. KATZ. [Price 5 cents.] No. 185. *Use of the Interferometer in Gas Analysis.* By FRANK M. SIEBERT and WALTER C. HARPSTER. [Price 5 cents.] Washington: Government Printing Office.

TRADING WITH THE ENEMY.—The Controller of the Foreign Trade Department has issued a new series (No. 64) of additions to the statutory list of firms of enemy nationality or enemy association with whom persons in the United Kingdom are forbidden to trade. Copies of this list can be obtained at a trifling cost from the Superintendent of Publications, H.M. Stationery Office, Imperial House, Kingsway, W.C.

PAYMENT BY RESULTS.

TO THE EDITOR OF ENGINEERING.

SIR,—I believe in payment by results, it savours of justice, and this is the only basis that successful industry can be built upon in England; the greatest, because the justest nation upon earth. This nation would not be much without her engineering industry, but unfortunately for the past forty years the blight of decay has been surely permeating every fibre of it, and since the war the spread of this disease has been at an alarming rate.

The pruning hook must be applied with an unrelenting hand or the whole great industry will disappear.

Industries, like trees which are allowed to grow naturally, attain vigour and permanence, but if the cultivators get obsessed with fads about training the branches to resemble a candlestick of the shekinah, the organism soon falls a prey to vermin and blight.

The engineering industry has not been allowed to grow naturally. The owners have taken their salaries as captains of industry and have left the work undone; and their deputies have been diplomatic, tactful, but often weak, and frequently unjust men; and the result has been that the works as a rule are like ships at sea which have parted with compass and chart.

It is not fair to blame the workers for the "chaos and old night" condition of the industry to-day. They are suffering from what the poet with rare insight called "want o' maisters": a terrible position for any class of workers to be in.

The engineering workers need masters to-day very badly; men who are truthful and just; and if they are not forthcoming speedily, nothing will save the industry from ruin.

To talk about curing the diseased condition, and bring up economic production to the level it should be at by applying a nostrum like "premium bonus," is an insult to our intelligence.

At this stage, prior to introducing a just system of payment by results, the most important operation is that of pruning: vigorous cutting out of dead formulas, platitudes, false hypotheses, erroneous conclusions, and adaptations of Prussian systems.

Where Bolshevik committees and rhetorical shop stewards have gained the upper hand on a plant, the just payment by result is instantly to dismiss the man who was masquerading as a master.

To say that the British workman needs inducements in the way of bonuses to get him to do his best is a slander; to say that he is not law abiding is equally untrue.

Given a *master* who knows his business, he will employ a man, pay him what he agrees upon, and he will see that the worker earns his money. On Saturday, the workman has what he agreed upon, and the master has the work performed which wanted doing. Each respects the other, and where just payment follows just work done there is harmony and progress, a condition of things foreign to strikemongers and fussy philanthropists.

Yours faithfully,

M. MACPHERSON.

18, Cambridge-street, S.W. 1.

TO THE EDITOR OF ENGINEERING.

SIR,—As everyone knows, "Payment by Results" is intended to satisfy the claims of labour, to bring about better understanding between employers and employees, and to improve the economic position of the Empire. It is a straight proposition, but Mr. McCarty's article in ENGINEERING of September 13, like many others bearing on this subject, does not recognise this. Two statements made by him are surprising:—

1. "Regarding the two better-known and more operated systems, *i.e.*, piecework and premium bonus, the writer is convinced that a lack of adaptability in the former and a want of complete understanding of the underlying principles of the latter are the main causes of their incomplete success. Piecework, except in the case of simple operations and large numbers of similar articles, is incapable of being successfully applied to shipbuilding and engineering generally."

The adaptability of both systems is identical, for "piecework" rates, properly fixed, are based on average attainments in the same way as "premium" times allowed. There is nothing in premium systems calling for exceptional understanding, but to suggest that there is, is, to put it mildly, to underestimate the intelligence of others—a very dangerous attitude.

2. "The employer must have a proportion of the saving (over and above his working expenses) sufficient to make him directly interested in the workman's bonus, without which margin he cannot be expected to work the system in the necessary free manner. This is quite apart from the advisability of the employer being in a position to reduce his selling price . . ."

Shipbuilders and engineers who are alive—and even those who are not—to the probabilities of post-war conditions, must, one should imagine, look upon the above assertion as a grossly inaccurate estimate of their business acumen.

In the course of a recent presidential address to the members of the North-East Coast Institution of Engineers and Shipbuilders, the following statement was made:—

"The question as to the share of each partner (Capital and Labour) in the product was an old one and seemed no nearer solution; and that it had been shown that labour under pre-war conditions took from eight to ten times the amount received by capital."

Mr. McCarty and those who agree with him favour the adoption of a retrograde policy. For, if it be assumed that the above proportions are equitable, they propose to divide the increment due to greater production, say, in the case of an average rise of 25 per cent. (ignoring oncost saving) in the ratios of 3 and 1 in place of 8/10 and 1. Taking similar figures to those given by Mr. Alex. Ramsay in his article in your issue of May 31—and those figures indicated practical knowledge, although I think he made a mistake in fixing the rate at 8*d.* per hour and estimating the price so as to enable the men to make 1*s.* per hour if the time allowed was occupied—a 25 per cent. improvement in output would give the following example of the saving effected on a basis job of 100 hours rated at 1*s.* per hour:—

		s.	*s.*
Time allowed, 100 hours at 1*s.* per hour	=	100	
Oncost (estimated on average experience) at 2*s.* per hour ...	=	200	
			300
Time taken, 75 hours at 1*s.* per hour	=	75	
Oncost as above + 20 per cent.*	=	180	
			255
Saving			45

Under the "Rowan" premium system the extra paid to the worker would be 18*s.* 9*d.* and the gain to the employer 26*s.* 3*d.* Without considering further examples showing better output results, it would almost appear that the advocates of premium systems expect to succeed in stimulating progress by reversing the pre-war ratios of recompense, in spite of the fact that increased production must involve presupposition of increased profit apart from the above saving.

In the past, the relations existing between employer and employee have been to a serious extent antagonistic. There have been faults on both sides, and the most essential purpose of "payment by results" is to overcome these; consequently there must be no curtailment of payment per unit of labour production provided improved appliances do not contribute. Surely the experiences of the past four years have provided sufficient evidence of the incalculable harm and loss sustained by tinkering with such a vital question; and the futility of academic, or should we say psychological perversions.

The writer is of opinion that a solution of the labour remuneration problem would be most nearly attained by the adoption of a scheme on the lines of that instituted by Messrs. Priestman Brothers, Limited, Hull. This firm, as many of your readers are probably aware, pay their employees on the basis of overhead weight production, and every class and official participates. The method of reckoning wages payable is simple and direct. Any increased production is paid for by adding to the standard or normal wage a percentage equal to the percentage of increased production. The firm is thoroughly satisfied with the results and every section of the workers has expressed unqualified approval of the system. The principles of the plan are perfectly clear; rate-cutting is eliminated; every employee shares in equal proportion in accordance with his status; and the most harmonious relations exist throughout the concern. Messrs. Priestman have found it to their advantage not only to pay for all increased output, but also, as a stimulus to their system, to pay 10 per cent. in excess of the amount earned by the extra output. Their system, if generally adopted, would, I am convinced, go far—now—towards reconstruction of the industrial situation and in removing the chief obstacle to national progress. Any objection which might be raised to weight fluctuations can easily be met by substituting overhead production expressed in labour units—the unit being fixed on the basis of times allowed to skilled workers.

In conclusion, it may be remarked that a very considerable number of employers fully appreciate the comment made the other day by a Conservative newspaper leader writer, when he referred to "the sturdy common sense and instinct of fairness which are inherent in the average working man"; but there are others who do not grasp the potentiality of a force which will be extremely powerful immediately the war ends.

Yours faithfully,

London, September 23. W. GROSART.

* Addition of 20 per cent. to cover extra depreciation, repairs and power.

MULTIPLE EFFECT COMPRESSION REFRIGERATING MACHINES.

TO THE EDITOR OF ENGINEERING.

SIR,—With reference to the article on "Multiple-Effect Compression Refrigerating Machines" in your issue of August 23, I beg to call your attention to an inaccuracy therein. In dealing with the question of power required in the two systems, after showing diagrams taken from the two kinds of compressors the writer of the article states:—

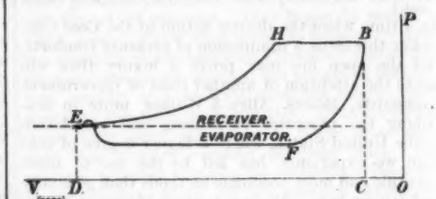
"Although the multiple-effect diagram is seen to be much larger in area . . . for that portion of the diagram which is between the lines indicating the pressures in the evaporator and the receiver is obtained without a corresponding expenditure of energy."

This cannot be correct. Taking the diagram obtained from the multiple-effect compression system—which I reproduce herewith—the work done by the gas on the piston when the piston is moving from right to left is given by the area B C D E F B. When the piston is moving from left to right the work done by the piston on the gas is given by the area B C D E H B. The difference between these two areas, which represents the energy to be expended in the compressor cylinder, and is the whole area of the indicator diagram, including that portion which lies between the receiver and evaporating pressure lines.

This is a matter of elementary mechanics, and is independent of any system of refrigeration.

In the preceding part of the article the writer states "That a machine built on the multiple-effect system will start with 25 per cent. more efficiency in this country . . ."

What precisely is the meaning to be attached to the term "efficiency" in this connection? From the context it presumably means output, or capacity, which



is quite different to what is generally meant by efficiency.

It is greatly to be regretted that such inaccuracies and looseness of expression appear not only in the article referred to, but quite frequently in matters relating to the refrigerating industry.

May we hope that the Refrigeration Research Committees formed in recent years will clear the air and put matters on a more satisfactory basis.

Yours faithfully,

G. W. DANIELS, M.Eng.

Ashton House, Elmsley-road, Mossley Hill, Liverpool.

September 5, 1918.

[We forwarded a copy of the above letter to Messrs. Seagers, Ltd., the makers of the machines referred to, and we append their reply.—Ed. E.]

TO THE EDITOR OF ENGINEERING.

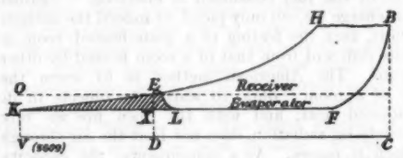
SIR,—We are greatly interested in Mr. Daniels' criticism of the article on "Multiple-Effect Compression," but we think that he has not understood what was endeavoured to be explained, and to make this more clear we repeat those portions of the article with which he deals, replacing in italics the words which he cut out. Our reason for doing so will become apparent.

The first portion of the article read as follows:—

"It is claimed that a machine built on the multiple-effect compression system, *weight for weight*, will start with 25 per cent. more efficiency in this country, and will have more than double the refrigerating power of an ordinary compression machine when it arrives in tropical regions."

This portion of the article compared simply the two systems of compression with regard to their weight and heat eliminating powers, but not their mechanical efficiency, so no misuse whatever was made of the word "efficiency."

By the actual alteration of an existing plant it has been proved that its efficiency as a cooler when served in this country with circulating water at 60 deg. and brine at 0 deg. F. is increased 25 per cent. or, more correctly, 27 per cent., but when served with circulating water at 90 deg. and brine at 0 deg. F. in the tropics its efficiency as a cooler is 130 per cent. to 134 per cent. greater than an ordinary compression machine. The



comparative mechanical efficiency of these machines can very easily be arrived at for different temperatures from figures which appear in a short paper which was read before the Cold Storage and Ice Association in 1913–14, a copy of which we enclose, and we will gladly supply other copies to any persons who are interested in the subject.

With regard to the power required for compression under the two systems, the article read as follows:—

"Although the multiple-effect diagram is seen to be much larger in area *than the ordinary one, the power necessary for compression is not proportionately greater*, for that portion of the diagram which is between the line indicating the pressures in the evaporator and the receiver is obtained without a corresponding expenditure of energy *by allowing the charge of gas from the receiver or high-pressure evaporator to enter the cylinder top of the charge which had been first received from the low-pressure evaporator. The entrance of this second high-pressure charge has the effect of raising the pressure of the first charge in the cylinder to its own pressure without any mechanical effort at the moment when the piston is at the end of its stroke.*"

If Mr. Daniels will again study the indicator diagrams, Figs. 3 and 5, in the article, he will find in the multiple-effect compression a much greater volume of gas than in the ordinary compression cylinder. This extra volume of gas, as was already explained in the article, is allowed to enter the cylinder at the end of each stroke at the moment when the crank is almost on its dead centre. It is evident, therefore, that the line of pressure is lifted from that of the evaporator to that of the receiver in almost an instant of time, whilst no effort whatever is being imparted to the piston, and the comparatively small cylinder is thus enabled to deal with a

volume of gas which in an ordinary compression plant would require a much larger cylinder to handle.

The introduction of this second charge has, moreover, a further advantage in permitting a separate evaporation and cooling of the gas before it reaches the lower-pressure evaporator, which would only become possible in other machines by using one cylinder for one evaporation and another cylinder for the second evaporation which has frequently been tried.

If Mr. Daniels will extend his research by plotting upon his diagram a cylinder proportionately longer by extending the compression curve until it meets the evaporator line, he will at once obtain a diagram which will approximately show the extra power required by ordinary compression to handle the same extra volume of gas as that shown on the multiple-effect compression card, but such an arrangement would, of course, only permit of one evaporation to be made. We send herewith a rough sketch of such a diagram, which we trust will make this matter perfectly clear.

Yours faithfully,
HENRY BRIER.
(SEAGERS, LIMITED, Dartford).

"COAL SAVING BY SCIENTIFIC CONTROL OF STEAM BOILER PLANT."

TO THE EDITOR OF ENGINEERING.

SIR,—One of your correspondents in the issue of ENGINEERING of the 13th inst. raises the important question of area over the firebridge, &c. Personally I prefer dispensing altogether with the bridge for hand-fired boilers as in stoker-fired ones, but close up to the ends of the bars, which at the rear we always fix 3 in. below the centre line of flue, a firebrick wall should be built and carried level with the bars for about 3 ft. along the flue, and the value of this will be apparent to all your readers. Where a firebridge is insisted on, the height from top of bridge to crown plate should not in any case be less than one-third the diameter of the furnace flue, but more if possible. I have tried the split bridge in various forms, and when means are carefully used to regulate the supplementary air, the results are an improvement on the solid bridge. I have not had any experience with the steel bridge.

I would point out that this discussion or rather comments on Mr. Brownlie's valuable report has been going on since and including July 26, and that in spite of the fact that all are agreed the present method of handling steam boilers is most wasteful, we are really no "forrader," although the notice "Burn less coal" is now as common as its predecessor, "Eat less bread."

Let us look at our evidence of coal wastage. In January last the final report of the Coal Conservation Committee was published, which indicates we are using about 5 lb. of coal per horse-power too much, which, on a total of, say, 12,000,000 h.p., equals a preventable loss of over 50,000,000 tons of coal per year. In July, Mr. Brownlie published his report of tests which included 1,000 boilers, and his figures give practical proof that the report of the Coal Conservation Committee was very modest, as he shows a difference of over 30 per cent. between his minimum and maximum examples.

TABLE A.—*Present General Practice.*

Size of Boiler.	Length of Grate.	Grate Area.	Square Feet of Grate Area to 1 Sq. Ft. of Outlet from Furnace Flues.	Chimney Draught per Minute.	Speed of Air through Furnaces per Minute.
ft. ft.	ft. in.	sq. ft.	sq. ft.	ft.	ft.
30 × 7	6 0	33	4	1000	250
30 × 8	6 0	39	3½	1000	285
30 × 8½	6 0	41	3	1000	333
30 × 9	6 0	45	2¾	1000	366

TABLE B.—*As Proposed to Secure General Economy.*

30 × 7	3 0	17	2	1000	500
30 × 8	3 9	25	2	1000	500
30 × 8½	4 3	30	2	1000	500
30 × 9	4 9	35	2	1000	500

We have in last week's issue the strong practical letter of Mr. Bennett giving details of his own experience, and after reading it no one wonders at the contents of the two reports mentioned above. I have carried out many boiler tests giving results ranging from 78 per cent. to 81 per cent. efficiency, and Mr. Brownlie had over 20 plants giving between 70 per cent. and 80 per cent. efficiency, and in some cases the latter figure was exceeded; why, then, should it be possible for any firm to work boilers below 50 per cent., as if, say, 75 per cent. to 80 per cent. was made compulsory a saving of well over 30,000,000 tons of coal would be effected. How this saving in coal can be secured was outlined very briefly in my letter which you published three weeks ago, and if such lines were generally adopted we should, by stopping coal wastage, prevent the much talked of coal shortage.

I have received a report to-day, September 19, from the chief engineer at a large public institution where four 30-ft. by 8-ft. Lancashire boilers are used for electric lighting workshop and laundry work. The firegrates in each boiler were originally 6 ft. long, the coal consumption 25 lb. to 30 lb. per square foot of grate per hour, evaporation 8.5 lb. of water per pound of coal burned, ratio of heating surface to furnace area 25 to 1. The firegrates have been shortened to 3 ft. 10 in., this increased the ratio of heating surface to grate to 39 to 1. Induced draught has been adopted, and the evaporation increased to 10.5 lb. per pound of coal burned, the overall efficiency of boilers and economiser is 85 per cent. or 28 per cent. above Mr. Brownlie's average, and 34 per cent. higher than the average at seventy-five collieries.

There is nothing special in the lay-out of this plant, with the exception of a CO_2 indicator, and from a chart I have seen the average carbon dioxide ranges from 14 per cent. to 15 per cent., the firemen are ordinary, and what is done in this case is possible with every steam plant in the kingdom, the saving of coal per boiler per year is nearly 200 tons.

The necessity for proportioning the areas of our boiler grates may be gathered by a careful study of the Tables A and B given above. A giving present general conditions, and B the proposals indicated in my letter of August 30.

Yours faithfully,
W. H. CASMEY.
Milnthorp, Wakefield, September 19, 1918.

THE DEFINITION OF HARDNESS.

TO THE EDITOR OF ENGINEERING.

SIR,—With reference to Professor W. C. Unwin's note on "The Definition of Hardness" in your issue of May 17, I would like to draw your readers' attention to the fact that in showing the identity of Brinell's and Martel's Hardness Numbers, it is assumed, although not explicitly stated, that k (intensity of pressure under which the material yields or flows in the conditions of the test) is a constant, dealt with as such in the subsequent calculations.

This would mean that when the force P increases from zero to its final value, the depth h of the indentation varies according to the law

$$\frac{P}{\pi (2 r h - h^2)} = \text{a constant.}$$

Is there any justification for this assumption?
Is it more justified than the simpler one—

$$\frac{P}{h} = \text{a constant } C?$$

By adopting this latter the work expended in indenting to a depth h_1 would be $C h_1^2/2$, and hence Martel's Hardness Number

$$D = \frac{C}{2\pi \left(r - \frac{h_1}{3}\right)},$$

and Brinell's Hardness Number

$$H = \frac{C}{2\pi r}$$

and

$$\frac{H}{D} = 1 - \frac{h_1}{3r} \text{ instead of } \frac{H}{D} = 1.$$

As far as I can see, out of all the possible equations of the type $P = F(h)$ Professor Unwin has picked the one that leads to $H = D$. But does this correspond to the actual facts? He might just as well have assumed straight away $H = D$ and have concluded from these that k is a constant.

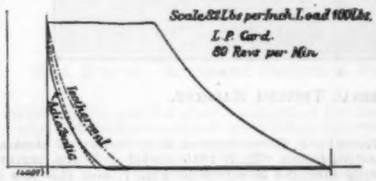
Or has Professor Unwin knowledge of any experiments or theory justifying his assumption? Many readers would no doubt be satisfied if this point was fully explained, as just now the whole question of hardness tests is again under discussion.

G. R. MAGNEL.
132, Ritherdon-road, Balham, Sept. 21, 1918.

"TESTING AIR COMPRESSORS."

TO THE EDITOR OF ENGINEERING.

SIR,—Mr. Walshe reproves me for making assumptions and then goes on making them himself; really it is amusing. He assumes that I was confusing the compression curve with the expansion curve; but he is wrong there. I enclose an indicator card taken from the intake cylinder of a two-stage compressor run under the most advantageous conditions for the purpose of finding out how the clearance volume air does really expand, and the card clearly shows that the curve terminates between the adiabatic and the isotherma



curves, and this under conditions that cannot be obtained in any quick-running compressor. I know that by running this machine at a much higher speed, say the normal speed of the machine, I could produce a card showing the expansion curve outside of the adiabatic curve, but I also know that it would not be a true indication of what was taking place, and that the improvement was due to the indicator only. Regarding the clearance volume, this can quite readily be measured by anyone more directly interested, when it would be found just how near 12 per cent. it is.

My assumptions as to the final air pressure in the first-stage cylinder and the surging effect at the intake, Mr. Walshe draws attention to, but makes no further mention. Why did he not correct me about them?

"Why make tests at all?" Mr. Walshe asks. Capacity tests I presume he means. Well, it is done, more often than not, to satisfy people who know very little about air compressors, for if they knew more they would understand that the result obtained would be only very approximate. I myself have seen a test sheet of a machine similar to the one in question, where the capacity test gave 93 per cent. volumetric efficiency, the indicator card showed 83 per cent., and the actual efficiency, taking into account internal losses, would be 3 per cent. to 4 per cent. less than 83 per cent. Can Mr. Walshe say that a test such as I describe was worth the time spent on it?

I am,
"INTERESTED."

TO THE EDITOR OF ENGINEERING.

SIR,—Our attention has been drawn to the report of a test on a 4,000-cub. ft. Bellis and Morcom vertical two-stage compressor appearing in your paper, and to correspondence which has arisen regarding this test. One of your correspondents criticises the method of air governing, and states that the Americans are far ahead of us in this matter. As makers of air compressors for many years we feel it our duty to write for the sake of our national reputation to deny this statement. We came to the conclusion many years ago, that to regulate the

quantity of air delivered by the compressor by opening and closing the suction pipe was elementary, severe on the motor, and quite unnecessary.

It is really a hit-and-miss system of governing, and who would look at a gas or oil engine of any size with this antiquated method of governing at the present day. We, therefore, patented and have now fitted large numbers of our compressors with an unloading gear which varies the compressor output by increments in exact accordance with the requirements from full output down to zero. The beautiful regulation of the gear is shown by the photo of an actual indicator card enclosed, and also a print from a tracing of this card as the photograph is not very clear, taken from an actual compressor. We do not know of any American results even to equal these, and it must be admitted it is impossible to beat them.

We remain, yours faithfully,
ROBEY AND CO., LIMITED
(*Per* F. B. PERRY).
Globe Works, Lincoln, England,
September 24, 1918.

MINERAL RESOURCES OF GREAT BRITAIN.—The Board of Agriculture and Fisheries desire to give notice of the publication of a second edition of Volume 5 of the Special Reports on the Mineral Resources of Great Britain, which have been prepared by the Director of the Geological Survey in response to numerous inquiries that have arisen through the conditions brought about by the war. In the main it is a reprint of the first edition, which deals with the occurrences and workings, past and present, of the minerals specified in the title. Some additional information on potash-felspars, steatite and diatomite has been inserted. Price 1*s*. Copies may be obtained through any bookseller from Messrs. T. Fisher Unwin, Limited, 1, Adelphi-terrace, London, W.C. 1, who are the sole wholesale agents to the trade outside the County of London; or from the Director-General, Ordnance Survey Office, Southampton.

LAUNCH OF A 1,000-TON REINFORCED CONCRETE VESSEL AT BARNSTAPLE.—Having been one of the 44 ports represented in the first Council of Shipping summoned by Edward III, and having been continuously engaged since the fourteenth century in the supply of ships and mariners for the commercial and other adventures which contributed so largely to the establishment of the British Empire, Barnstaple has an honourable record as a shipping port and shipbuilding centre. At the beginning of the nineteenth century, shipbuilding was carried on at four yards, the chief being that of Robert Westacott, who died in 1812. Some years before 1850, the yard was removed lower down the river, and was the last yard in the port to be closed down owing to the competition of iron and steel shipbuilding. It happens very appropriately that the revival of the shipbuilding industry in Barnstaple this year is due to the enterprise of Mr. Percy Westacott, a descendant of Robert Westacott and head of the British Contruction Company, of Westminster. Moreover, the shipyard branch of this undertaking occupies the site of the old Westacott yard, but instead of being used for the building of wood vessels it is employed in the construction of ferro-concrete sea-going barges and steam tugs on the Mouchel–Hennebique system, and extensions lower down the river are contemplated in order to provide for the building of concrete ships up to 10,000 tons deadweight capacity. In March last, the site was simply meadow land, but was rapidly covered by workshops, storehouses, slipways and other necessary structures and plant. The keel of the first 1,000-ton barge was laid on May 10, and others soon followed until four barges and three steam tugs were in various stages of construction. The first barge was launched on Saturday last. The vessel is 187 ft. 6 in. long overall, 31 ft. 6 in. in beam at deck level and 20 ft. 9 in. deep from deck to keel. It includes three holds for cargo, quarters for captain, mate and crew, and accommodation for boiler plant, coal and stores.

SOME USEFUL TESTING MACHINES.*

AT no previous time have engineering firms been called upon to do so much physical testing as now to ascertain the suitability of their products, and the privilege has not been given to many of finding themselves efficiently equipped and staffed to undertake the work in their own laboratory or testing department. It has been the great privilege of the writers to be associated for some time past with firms, of which the managing directors have been sufficiently broadminded to assist their neighbours in the making of tests, and they venture to claim that not only is this action much appreciated by those concerned, but that the efficiency of the area has been considerably increased in consequence of the advice secured. The authors take this opportunity of thanking Mr. F. H. Crittall and Sir Wilfred Stokes, the managing directors of their respective firms, for permitting them to place before the Institute the first-hand descriptions of the several testing machines employed in their laboratories, and also of some of the interesting data obtained by their use. The prime considerations which caused the selection of most of the machines described were their moderate cost and short time of delivery, and other, but no less important points, were their simplicity and convenience for commercial testing, combined with the accuracy of their determination of the various physical properties of metals. Some of the machines are illustrated in Figs. 1 to 7; others will be issued later.

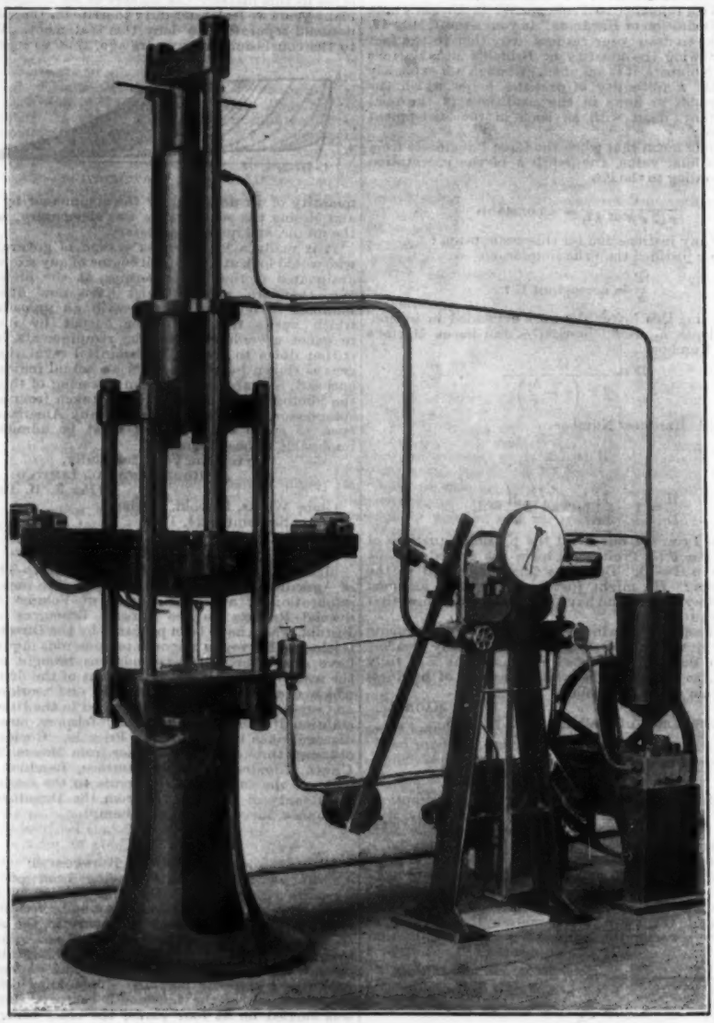


FIG. 1. 30-TON AMSLER UNIVERSAL TESTING MACHINE.

Tensile Testing Machines.—Whilst for a long time we have been almost exclusively confined to the use of lever machines in this country, the use of lever testing machines has been almost entirely abandoned on the Continent, and also to a large extent in America. The hydraulic method of applying the load is nearly universal, but in most cases an independent system of measuring the stress is necessary, and few rely wholly upon the simple pressure-gauge method for accuracy and continued reliability. One class of machine is so designed that the application of the load and its simultaneous measurement is accomplished by the same pressure system, and this, of course, constitutes a very simple, convenient and compact machine, which has no knife edges or springs to go wrong, and is further entirely free from inertia effects which are so fruitful a source of error. This principle is adapted to the vertical form of testing machine by Messrs. Amsler Brothers, of Switzerland, and their combination of press and pendulum gauge is recognised by the Association of Testing Materials as universal; it is constructed in a variety of sizes and standard forms. Their 1916 model of 30-ton universal testing machine is shown in Fig. 1, and this has the various arrangements whereby round, flat and headed test bars may be tested in tension; it enables bending, transverse and compression tests to be performed, and by means of easily adjusted bolsters it permits hardness, shearing, or punching tests to be made with the minimum of trouble.

The entire machine comprises three parts, the first of which is the press with a steel ram operated by compressed oil. The fit in the cylinder is sliding, so that friction is negligible owing to the small constant stream of oil escaping while the machine is at work. The pressure of oil is conveyed from the ram through a cross-head with a hardened steel socket, to two steel bars freely supporting the cradle or moving head. The crown is secured to the base by four stout steel bars which support the superstructure, and these endure the maximum load of the machine without appreciable deformation. The base itself is a hollow iron casting with a steel table to anchor the wedge grips or other shackles, and no great strength is required in this stand as it supports no part of the loading, nor does it require to take any overhang since the centre of gravity is not moved during the conduct of the tests. Tensile and shearing tests are made by securing the test bars between the base and the cradle, and compression, punching, bending and transverse tests are made between the cradle and the crown without any elaborate fittings. To raise the moving head to any required position the pressure oil is admitted by the valve at the right of the press, and to lower it again by gravity it is sufficient to open the release valve on the pressure gauge, and let the oil return to the reservoir in the pump.

The high-pressure oil pump is the second part of the apparatus, and it may be driven by either belt or motor. The oil supply is delivered by three pistons at a steady pressure up to 3 atmospheres, and the suction valves are controlled by a handle which lets the motor run light when in the "Off" position, but forces oil through the pipes when in the "On" position. If all other valves in the pressure gauge and press are closed, then the oil is simply short-circuited, by a spring-controlled valve, back into the reservoir.

The third part of the assembled machine is a simple and accurate form of direct-acting pressure gauge or pendulum manometer, which measures the force exerted on the test piece by the oil pressure. This it does by displacing a freely hung pendulum from the vertical position so that the pointer of the gauge constantly indicates the force exerted by the automatic balance effected by the pendulum. Details of the pressure gauge and regulators are shown in Figs. 2 to 4. Pressure oil enters by pipe A, and may be short-circuited by a spring at the back of the regulator R into the pipe B, and large return pipe C communicating with the oil reservoir. On opening the valve V_1, oil flows by the uptake pipe D to the cylinder of the press, and thus elevates the ram. The release valve V_2 on the left of the manometer puts the pressure pipe E into communication with the return pipe C. When load is placed on the specimen the oil pressure is conveyed by pipe F to the small cylinder S, which causes the piston P to move without friction due to its rotation and the slight escape of oil. The force which expels the piston P is transmitted to the two vertical rods G bolted together by a distance-piece at the bottom, and attached to a short block lever H at the top through ball bearings. The movement of H causes the shaft J, mounted in the manometer frame with ball bearings, to rotate and deflect the pendulum from its normal position till it assumes a position of equilibrium. The pendulum rod can be suspended from several different points giving a variation in the sensitiveness of the machine.

Sensitive records of the variations in the loading of the test bar are secured in a unique manner. Attached to the front end of the rod J is a short steel arm parallel to the pendulum, and moving against a screwed rod L, which not only actuates the pointer moving over the scales of the dial K, but also carries a sliding pencil holder. The tracing pencil moves over the diagram paper clipped on to the brass drum which rotates smoothly when actuated by the chord from the extensometer attached to the test bar. With short bars it is often sufficient to take the travel of the cradle relative to the base for commercial purposes, and this also saves the removal of the extensometer prior to rupture of the bar. When the bar breaks the pendulum falls back freely for but a short distance, as the oil escaping from the cylinder S has to do so by a small bye-pass so that the motion is comparatively slow and without jerk. Although the pressure gauge is so sensitive, there are no weak parts in it to go wrong, as it is throughout of the most robust construction, and yet it is not unwieldy. It simply requires to be bolted to the floor sufficiently level to let the pendulum swing in a perfectly vertical plane. The rotation of the screwed rod L, whilst holding the pencil carrier, enables the pointer to be readily adjusted to zero at any time. Measurements on the autograph diagram are facilitated since the complete rotation of the pointer over the scale gives a travel of 10 cm., corresponding to the maximum load for each sensitiveness.

Other Tests.—To make transverse or bending tests, two roller supports are fixed at a convenient distance apart in the cradle by means of the side screws which engage the cross bars sliding in a slot which runs the full length of the cradle on each side. The middle support to apply the bending, is suspended by a pin let into the side of the crown, and this only requires to be withdrawn to let it fit into a slot encircling the head of the support. This may be provided with a roller like the side bolsters, or it may be simply a rounded die to effect the bending test when the supports are moved into close proximity. The centrally-held die may be provided with a spring clip holding a 10 mm. ball to perform Brinell hardness tests when the cradle is raised with the specimen to effect the compression.

Compression tests are very simply made on test pieces placed between two hardened steel discs, one of which is held in the middle of the cradle by a square foot-step, and the other is supported from the centre of the crown by a circular bolster provided with a spherical seating to ensure the crushing faces being parallel. Crushing tests are now more commonly specified than formerly, and interesting results are often obtained with metal which have been variously heat-treated and worked, as shown in Table I. The first section shows the toughening effect of oil quenching upon a medium carbon steel for power press screws, the second deals with the forging of ordinary cast-iron between dies in the press, and the third part shows how much even the strongest brass may be improved by mechanical treatment at the right temperature.

For making shearing tests, special yokes are fixed by the cross bolts through the baseplate and the cradle. These two portions are provided with hardened steel cylinders with a hole through each for carrying the test bar. Accurate alignment is secured by screwing up

* Abstract of paper read by Mr. H. S. Primrose, M.I.M., metallurgist, Messrs. Crittall Manufacturing Company, Limited, Braintree, and Mr. J. S. Glen Primrose, A.R.T.C., metallurgist, Messrs. Ransomes and Rapier, Limited, Ipswich (members of the American Society for Testing Materials), before the West of Scotland Iron and Steel Institute, February 15, 1918.

collars at the end, thus preventing any play between the shearing faces. By selecting a test bar diameter nearly equal to the central opening in the hardened cylinders, the test-piece can be readily inserted and sheared without any considerable amount of bending such as usually accompanies this test.

TABLE I.—*Effect of Mechanical and Heat Treatment on Compression Strengths of Medium Carbon Steel, Cast-Iron, and Brass.*

0·45 per Cent. Carbon Steel.	Compression Elastic Limit.	Brinell Hardness Number.
	tons per sq. in.	kg. per sq. mm.
Normal { Long.	47·5	185
" { Trans.	42·5	180
Single oil quenched { Long. ..	93·8	365
" " { Trans. ..	92·0	340
Single water quenched { Long. ..	91·0	340
" " { Trans. ..	89·5	340
Double oil quenched { Long. ..	85·3	320
" " { Trans. ..	82·5	320

Medium Carbon Cast-Iron, Forged at 850 deg. C.	Ultimate Tensile Strength.	Compression Elastic Limit.	Ultimate Crushing Strength.	Reduction of Length before Cracking.	Brinell Hardness Number.
	tons per sq. in.	tons per sq. in.	tons per sq. in.	per cent.	kg. per sq. mm.
1st Set—Water cooled	12·5	30·2	59·8	26·8	165
2nd Set—Air cooled	11·0	28·8	58·6	23·1	150

Beta Brass for "A" Metal, Forged at 650 deg. C. and Air Cooled.	Ultimate Crushing Strength.	Tensile Tests.				Brinell Hardness Number.
		Elastic Limit.	Ultimate Strength.	Elongation on 2 in.	Reduction of Area.	
	tons per sq. in.	t. per sq. in.	t. per sq. in.	p.c.	p.c.	kg. per sq. mm.
1st set ..	62·7	22·6	40·2	23·1	22·3	170
2nd set ..	61·0	21·2	39·4	21·5	25·0	165
3rd set ..	59·8	20·6	39·8	23·1	23·9	165
4th set ..	58·0	20·0	38·2	28·4	28·7	160

Values given are the average of four tests.

Punching tests also give useful information as to the behaviour of metal under other stresses, and it has even been claimed that this test gives a better average value from which the tensile result may be calculated than the direct tensile test itself, since the latter deals with a much smaller section than that cut by the punch. The punching test as performed in the compression part of the testing machine only requires a simple bolster to carry the punch and die in correct alignment, and to withdraw the punch without displacement of this after the flat test piece has been pierced. Several corresponding values of the ultimate tensile, punching and shear stress of several grades of steel are given in Table II and show that simple relationships can be established between these values.

TABLE II.—*Relationship of Tensile Strength with Punching and Shear Stresses for Various Steels.*

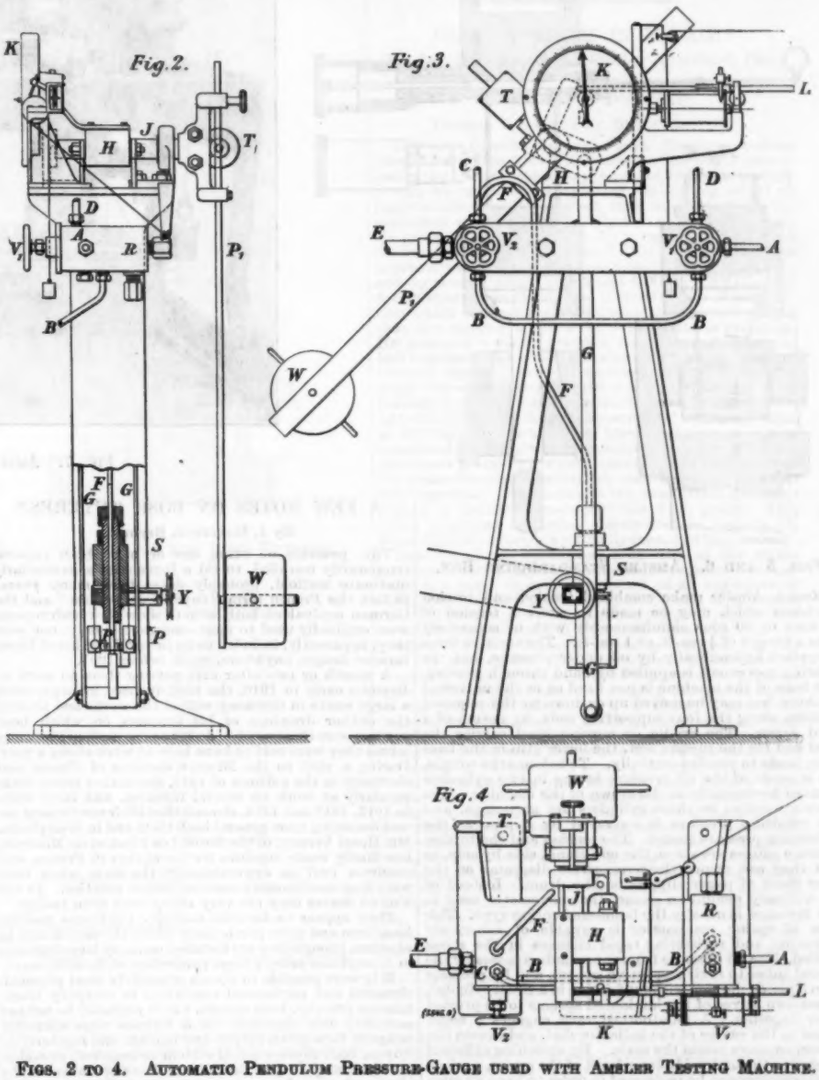
Average Tensile Strength.	Actual Punching Stress.	Shearing Stress.
tons per sq. in.	tons per sq. in.	tons per sq. in.
21·3	18·3	10·1
25·0	19·2	11·8
28·1	21·5	12·9
32·0	23·7	14·3
34·5	25·5	15·2
39·0	28·0	16·8
43·0	30·7	18·0
47·5	34·1	19·6
"T"	0·65 T + 3·18	0·35 T + 3·0

When autographic diagrams are taken of the punching and shearing tests, valuable information is got as to the practical value of the metal, its ductility and behaviour in practice. The yield-point in shear stress is easily observed and serves to place the metal in the class to which it belongs.

Standardising.—Even although it is usual for each testing machine to be accurately calibrated by the makers and guaranteed to be correct, it is usually advisable to check them occasionally to ascertain if there is any variation during service. To do this, it is sometimes considered necessary to lift standard weights on the testing machine itself. Otherwise a standard bar of known modulus of elasticity may be submitted to tension within its limit of proportionality, but this necessitates precision instruments to measure the deformation. The crushing of a number of small copper cylinders of known reduction of length for a given load may be adopted, but no very great accuracy may be expected from this method. To overcome these difficulties Messrs. Amsler have invented an ingenious standardising box which is light and easily handled. It can be used without expert knowledge to check testing machines either in tensile or compressive stress, both quickly and with as great exactness as by the dead-load method.

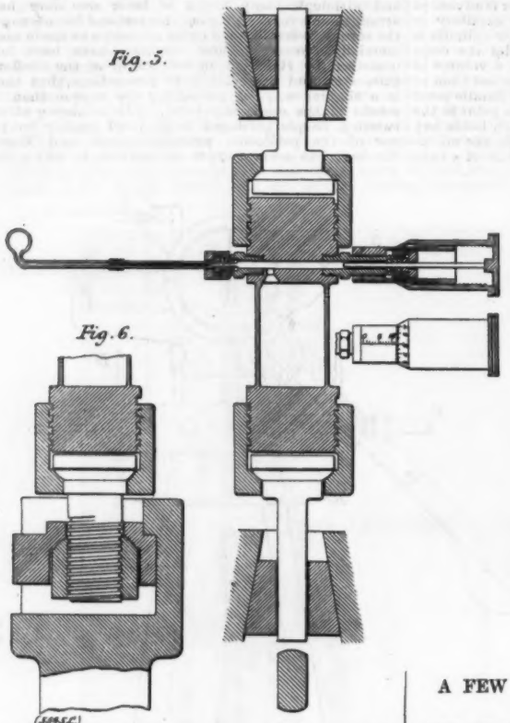
As shown in section in Figs. 5 and 6, the box consists of a hollow cylinder of special steel filled with mercury which extends into a horizontal capillary glass tube projecting from the box. The tube is provided with a zero mark to which the mercury is adjusted by a micrometer screw, the stem of which projects into the enclosed space filled with mercury, and when the screw is advanced or withdrawn it pushes mercury into the capillary or withdraws it into the box. When the hollow cylinder is stressed axially the volume decreases under the compression or increases under tension so that a volume of mercury equal to this volume change is expelled from or pulled into the box. Thus the micrometer handle must be turned to restore the mercury to the zero point in the capillary tube, the bulb at the end of which holds any excess and prevents its escape. The scale on the micrometer enables the observer to read hundredths of a turn of the handle, and this gives a measure of the change of volume of the steel cylinder, which being thin-walled to give large displacements of mercury (easily observed), must not be stressed above its elastic limit. The readings of the micrometer which are proportional to the loading of the box, are independent of the size of the capillary tube, so that if one is broken it can be replaced by another without re-standardising the instrument by dead loads as is done in the first instance. The micrometer can be turned at pleasure to any position so as to admit of its being easily read when in place in the testing machine. In making compression checks, it is necessary to ensure that the box is placed between two perfectly flat surfaces parallel to one another in the crown and cradle of the machine. The extension boxes for tensile standardising have screw heads with extension pieces to be gripped either in the wedges or in the spherical seatings of the other shackles. These boxes are made in two forms, one for measuring compression only, and the other for either extension or compression, the former ranging up to 120 tons, the latter up to 30 tons. To convert the double-purpose boxes from tensile to compression use, it is only necessary to screw off the heads of the end extensions. As the constants of the micrometer readings for compression differ slightly from the same stress readings in tension, the two sets of constants are stamped on the boxes.

Torsion Testing Machines.—The importance of this useful method of determining the shear strength of metals has been recognised only comparatively recently, and although many forms of lever machines have arrangements for carrying out this test and for measuring the torque, it is still not a common test to be made commercially. Some of these machines have been fully described by Hailstone in vol. xxviii of the Staffordshire Iron and Steel Institute proceedings, but there is a simpler way of measuring the torque than by means of the customary lever. The balancing of the twisting couple produced lends itself readily to the use of the pendulum pressure gauge, and Messrs. Amsler make several types of machine in which this principle is used. The smaller hand size for torsion testing alone is illustrated in Fig. 7, which shows the machine to consist of a rigid frame with two heads, the fixed one for applying the torque, and the other moving on ball bearings and carrying the pendulum. The bar to be tested is screwed in jaws in the two heads, which take flat bars or rounded ones if provided with rectangular heads. The torsion couple is produced by a pulley driven by belt or worked by hand, and the rotation is transmitted to the test bar by worm and wheel. The pendulum, suspended from the moving head by an axis which rotates in ball bearings, serves to balance, by its inclination from the vertical position, the torque developed in the test bar. The weight of the pendulum bob is easily changed by removing parts of it which are bolted on, so that the sensitiveness of the machine can be increased by diminishing the maximum torque from the full 150 kg.-m. (say, 1,100 lb.-ft.) to 100 kg.-m. and to 50 kg-m. The angular displacement of the pendulum in conjunction with the angle of twist of the test bar gives a means of autographically drawing a diagram of the test. The movement of the pendulum-carrying head along the frame of the machine prevents the test bar from being subjected to the slightest tension as it shortens under the twisting it receives.



FIGS. 2 TO 4. AUTOMATIC PENDULUM PRESSURE-GAUGE USED WITH AMSLER TESTING MACHINE.

SOME USEFUL TESTING MACHINES.



FIGS. 5 AND 6. AMSLER STANDARDISING BOX.

Messrs. Amsler make combined tension and torsion machines which may be made to exert a tension of 30 tons or 50 tons simultaneously with or separately from a torque of ½ ton-ft. or 1 ton-ft. The tractive force is applied hydraulically by oil under pressure, but the twisting movement is applied by hand through gearing. The base of the machine is not fixed as in the universal machine, but may be moved up or down to the required position along the four supporting rods, by means of a hand screw. The cradle or moving head carries the fixed end for the torsion test, the lower grip in the base being made to revolve centrally. To balance the torque, use is made of the oil pressure set up in two cylinders situated horizontally in the crown of the machine. The pistons working in these cylinders act as pumps, and the resulting pressure is conveyed by a pipe to the registering pressure gauge. The tension and the torsion pressure gauges are set on the one stand, side by side, so that they can record their respective diagrams on the same sheet of paper clipped on the drum. Instead of the ordinary pendulum gauge, the manometer used in this instance is usually the laminated spring type. This form of spring manometer is capable of accurately indicating and registering rapid changes in the stress applied. The oil pressure from the cylinders passes by the several tubes to their respective gauges, and by pressing upon a piston moving without friction in a small cylinder, causes two leaves of the laminated springs to be pressed closer together. A fine-toothed rack engages a small pinion in the centre of the indicator dial, and causes the pointer to move round the scale. By attaching different weights to the underside cross-head of the gauge, various sensitivenesses can be registered in order to have an open scale for each reading. The balancing of the different stresses exerted on the test bar is thus automatically effected, and it leaves the operator free to perform the complex test, since after he has started the tension force by admitting the pressure oil to the top cylinder, he can give his attention to the application of the twisting couple by hand, the diagrams being autographically produced.

(To be continued.)

GERMAN IMPORTS BEFORE THE WAR.—Of the pre-war imports into Germany, of which the value was 10 milliards of marks, 5 milliards were raw materials and 3 milliards food-stuffs and tobacco. Some of these Germany has done without during the four years of war, while for others substitutes have been found. Many sacrifices have been made. In the cotton trade, of 1,700 spinning and weaving factories, only 70 large ones are working; in the silk trade, of 45,000 looms, only 2,500 are at work; in the oil industry, only 15 out of 720 businesses are still active, while in the boot and shoe trade half the firms are closed. And after the war, when millions cease from war work, much raw material will be required, but German writers assert that many war substitutes will continue to be used after the war.

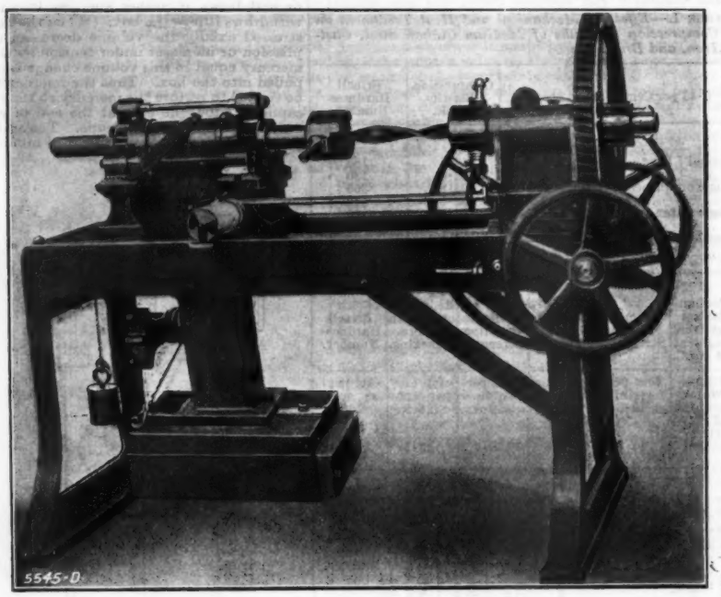


FIG. 7. AMSLER TORSION TESTING MACHINE.

A FEW NOTES ON BOSH TUYERES.*

By J. HOLLINGS, Brymbo.

THE practice of using one or more bosh tuyeres, temporarily installed, to rid a furnace of a particularly obstinate scaffold, probably dates back many years; in fact the French term "tuyeres de secours" and the German equivalent both seem to show that bosh tuyeres were originally used to meet emergencies only, nor were they, apparently, included as an integral portion of blast-furnace design, anywhere, much before 1907.

A month or two after first putting them to work at Brymbo early in 1910, the blast-furnace manager from a large works in Germany visited the works and showed the author drawings of his furnaces on which bosh tuyeres were illustrated. As far as the author's memory serves they were said to have been at work about a year. During a visit to the Minette districts of France and Germany in the autumn of 1910, the author found them regularly at work on several furnaces, and later visits in 1912, 1913 and 1914, showed that their continuous use was becoming more general both there and in Westphalia. Mr. Henri Verney, of the Société de l'Industrie Minérale, has kindly made inquiries for the author in France, and confirms 1907 as approximately the date when they were first continuously used in French practice. In the United States they are very rarely used even to-day.

They appear to be used mainly on furnaces making basic iron and more particularly where the slag is high in alumina, though they are installed on many large furnaces in Westphalia using a large percentage of Swedish ore.

If it were possible to obtain absolutely ideal physical, chemical and mechanical conditions in everyday blast-furnace practice, bosh tuyeres would probably be neither necessary nor desirable. If a furnace were correctly designed for a given output and burden, and regularly so driven, bosh tuyeres would seldom be required, provided the size and quality of the burden, the temperature of the blast and other furnace conditions were kept as regular as is easily practicable on a modern furnace plant. Unfortunately even regular driving cannot be depended on in these days when supplies of raw materials are a source of frequent difficulty, and there is always the temptation to get more out of a furnace than it was designed for. Blast-furnace practice must always, and more especially to-day, be to a great extent a series of compromises, and bosh tuyeres are one of them.

The circumstances which led to the adoption of bosh tuyeres at Brymbo were several years' bitter experience leading to the conclusion that as far as conditions there were concerned the absolutely regular descent of the burden was of greater importance than the absolute regularity of any one other factor in furnace practice.

The furnace which caused so much trouble would now be considered a mere toy, being only 48 ft. high from hearth to stock line, 8 ft. 6 in. in hearth diameter, and 8,500 cub. ft. capacity. During the last eighteen months of her campaign she averaged, however, over 700 tons of basic pig-iron per week on a 38 per cent. burden, which meant that the iron in the ore charged at the top was tapped as pig-iron 8 hours later. She had made 550 tons a week and had run months without scaffolding on many occasions, but very different conditions arose when the make was pushed to 700 tons and even 750 tons a week. Similarly, a furnace making 1,000 tons a week on a 37 per cent. burden became an entirely different proposition when it was attempted to obtain the same weekly output from a 30 per cent. burden.

Having done everything which at the time seemed feasible to ensure regularity in the size and quality of the burden and its proper distribution into the furnace, and being still troubled with scaffolds, it was decided that the easiest way to obviate them was to instal a second row of tuyeres at some distance above those in the hearth. No information was forthcoming as to the correct height above the hearth for such tuyeres, so we set about getting it for ourselves on the larger of the two furnaces mentioned above, which had then been blowing about eighteen months.

Holes were made at points A and B, Fig. 1, above the mantle plate; 1 in. diameter steel pipes were securely fastened in them and registering pressure gauges installed on branch pipes in such a way that a rod could always be passed through the 1 in. diameter tubes to clean them preparatory to taking each reading. In practice this did not prove necessary, as the tubes were hardly ever found obstructed in any way. Moreover, holes drilled at various points in the casing above the mantel plate entirely failed on every occasion to locate any accumulations on the walls above the bosh. One small bosh tuyere was specially installed at C, and readings of the pressure inside the furnace were taken at regular intervals by means of a very simple apparatus. A similar apparatus served to take readings at the centre of the hearth through the ordinary tuyeres. This apparatus was pushed through the bosh or hearth tuyere, the pressure read, and the apparatus withdrawn in about 30 seconds.

Readings were taken at Points A, B, C, and D, shown in Fig. 1, every hour to begin with, but the difficulties of keeping the bosh tuyere open with blast only going through it for a few minutes together at intervals of an hour were so great that after two days, readings at this point were given up. In normal practice, the other readings were so regular that after a week we only took readings during periods of abnormal pressures.

The furnace was being blown with a regular volume of air, irrespective of pressure, to a point. The normal blast pressure was 5 lb. per square inch in the horseshoe main; this was allowed to rise to 9 lb. per square inch before the volume of air was lessened. If the pressure in the horseshoe main rose above 9 lb., the volume of air reduced so that the pressure should under no circumstances exceed 9 lb. Readings taken over a period of one month showed that though the pressure at C and D varied over a range of 5 lb., the pressure at A and B never varied more than ½ lb. Moreover, this latter variation was probably due to some extent to the size of the material charged into the furnace. The supplies of ore came in on Mondays, Wednesday and Fridays, and by Sunday morning the bunkers were getting empty and most of the material drawn from them was on the fine side. It was invariably at such times that the pressure at the points A and B, shown in Fig. 1, was at the maximum. Clearly, therefore, the obstructions when they arose were situated between C and B.

It was, therefore, decided to instal four bosh tuyeres at a height of 9 ft. 4 in. above the centre line of the hearth

* Paper read before the Iron and Steel Institute, Friday, September 13, 1918.

tuyeres. Each bosh tuyere is surrounded with a cooler and rigged in a manner exactly similar to the ordinary hearth tuyeres.

The view was taken that the use of bosh tuyeres was incorrect, theoretically, and being anxious not to overdo the quantity of blast, introduced at this point, an internal diameter of 2½ in. was selected for the bosh tuyeres. A few weeks' experience showed that this was on the small side, and the diameter was increased to 3 in., and subsequently to 4 in. The nose of the tuyere was not more than 3 in. beyond the brickwork of the bosh, which consisted of a complete riveted steel plate sheeting, lined with 13½-in. brickwork.

No break through has ever occurred anywhere in the bosh, nor has a hot spot above the bosh tuyeres ever been noticed, though on rare occasions hot spots occurred above the hearth tuyeres before the bosh tuyeres were installed.

The table below gives a summary of information that a number of friends in this country have been kind enough to give the author, and Fig. 2 serves as a key thereto. The table shows that the number, size and position of bosh tuyeres vary over a fairly wide range at different places.

As to the results to be obtained by the use of bosh tuyeres the author can here speak only from his own experience, and must rely on the members present to confirm or refute it from their own.

The figures given were obtained from a furnace with a hearth diameter of 11 ft., a bosh diameter of 19 ft. 8 in., a stock line diameter of 14 ft., and a bell diameter of 9 ft. The height from hearth to the bottom of bosh was 7 ft. 3 in., from the bottom of the bosh to the top of the bosh 13 ft., and from the top of the bosh to the stock line 32 ft. 9 in., the total capacity below the stock line being 12,600 cub. ft. (see Fig. 1). This furnace is blown with eight hearth tuyeres, those on either side of the tap hole being 5 in. diameter, while the other six are 5½ in. diameter. The air blown when bosh tuyeres are in use varies from 14,000 cub. ft. to 16,000 cub ft. per minute, according to the coke available, and in normal practice the pressure is 6 lb. per square inch.

The furnace was blown in in the late autumn of 1908, and during the whole of 1909—running on a 35 per cent. burden—made an average of 778 tons of iron per week, 74·9 per cent. of which contained less than 1 per cent. of silicon, and less than 0·1 per cent. of sulphur. The coke consumption over the whole period averaged 22·4 cwt. per ton of pig-iron. Throughout this period the furnace was working without bosh tuyeres, and

TABLE.

—	A.	B.	C.	D.	E.	F.	G.	H.	Tuyeres. Bosh.		Tuyeres. Main.	
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	in.	in.	No.	dia. in.	No.	dia. in.
1	20 0	12 6	8 0	5 6	9 0	6 0	6	4	5	4	8	5
1 (a)	18 6	11 6	7 6	5 3	8 5	9 4	6	4	6	4	8	5
2	21 0	13 0	—	6 6	10 7	2 6	9	–	6	3	12	5-6
3	19 10	11 0	—	5 6	6 6	12 9	9 to 5					
3 (a)	19 10	11 0	—	5 6	7 6	11 9	3	5	5	{ 4 to 3½	9	6
4	20 0	12 6	—	7 10	10 7½	0 10½	9	6	4	6	8	5½
5	19 0	11 0	—	5 3	9 5	3 10	6	4	5	4	8	5
5 (a)	21 9	12 6	—	7 0	10 9½	3 11½	6	4	5	4	10	6
6	19 8	11 0	7 3	5 3	9 4	5 10	6	2½	4	2½	8	5
6 (a)	19 8	11 0	7 3	5 3	11 0	4 2	6	3	4	4	8	5

troubles with scaffolds were not infrequent, particularly when any attempt was made to increase the driving. Bosh tuyeres were inserted early in 1910. During the coal strike in 1912, the stock line was repaired, and over the whole of 1913 the furnace was running with four bosh tuyeres, at least three of which were continually open. The average make per week on a 37 per cent. burden was 1,016 tons; 89 per cent. of which contained less than 1 per cent. of silicon and less than 0·1 per cent. of sulphur. The coke consumption during this period was 23·1 cwt. per ton of pig-iron. The two years, 1909 and 1913, are given, because in each case the furnace lining had only been in use about a year, and, as far as the condition of the furnace itself is concerned, the comparison therefore is a sound one.

After allowing for the fact that the burden in 1913 was 2 per cent. richer than in 1909, the increased output due to the use of bosh tuyeres may be estimated at approximately 20 per cent.

During the year 1916, the furnace was working on a very much leaner burden; the average throughout the year was only 30 per cent. With this, the average make was 872 tons a week, of which 85 per cent. contained less than 1 per cent. of silicon, and less than 0·1 per cent. of sulphur. The coke consumption on this burden was 25·9 cwt. Bosh tuyeres were used throughout the year.

As a result of his experience, the author would have no hesitation in providing for the inclusion of bosh tuyeres in any new furnace in which it was intended to make basic iron; they could then be rapidly installed if occasion arose. The figures given will show that their continuous use at Brymbo has meant not only a very considerable increase in the quantity of iron made, but a greater regularity in its quality. Against this, it cannot be denied that the coke consumption per ton of pig-iron has been increased to a slight extent. By keeping the proportion of air blown through the bosh tuyeres to the lowest practicable minimum, the increase in coke consumption has not exceeded ¼ cwt. per ton of pig-iron, which is a small price to pay for the other advantages derived. Part of this increase may be due to the increased speed of driving. On a given burden there is a maximum economical speed of driving for every furnace; any lower rate of driving results in increased fuel consumption to meet the greater radiation losses, and on the other hand any higher rate of driving involves incomplete preparation of the burden in the upper part of the furnace, and greatly increased work in the melting zone and the hearth, with a correspondingly increased fuel consumption.

When the furnace referred to is making 1,000 tons a

Fig. 1.

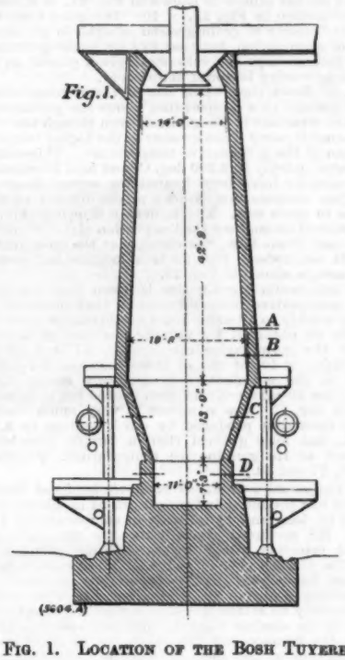


FIG. 1. LOCATION OF THE BOSH TUYERES.

Fig. 2.

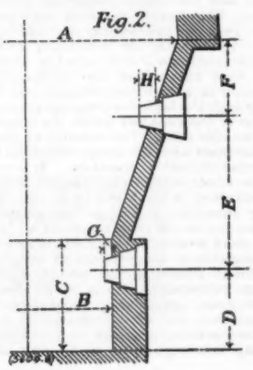


FIG. 2. DIMENSIONS SHOWN IN ACCOMPANYING TABLE.

week, her output of pig-iron per 24 hours is 1 ton for every 87 cub. ft. of furnace capacity, whereas for the most economical results from the burden we are using it should not exceed 1 ton of pig-iron per 24 hours for every 100 cub. ft. of furnace capacity.

All the tuyeres at Brymbo—both hearth and bosh—are installed on a sytem which was patented some years ago by Mr. W. J. Foster. The patent has, the author believes, run out, but his experience of the system has been so entirely satisfactory that he ventures to allude to it here.

The water inlet pipes to the tuyeres are coupled to a ring water main round the furnace in the usual way, but, in addition, the discharge pipes are all coupled to a similar main placed below the tapping platform. This main is coupled to a syphon or pump, so that it is always under partial vacuum. In this way, though the water passing through the tuyeres may be greater in volume than in the usual system, the pressure in the tuyeres themselves is zero or below, and consequently it is possible to run with quite a large hole in a tuyere and yet admit no appreciable quantity of water into the furnace hearth. Not infrequently a tuyere has been taken out which on examination proved to have a hole 4 in. long, varying in width from $\frac{1}{16}$ in. to $\frac{1}{4}$ in., and yet the failure of the tuyeres had not involved any change in the grade of iron we were making.

Many furnaces are constructed with the tapping platform only very slightly above pig-bed level; in these instances, it is not such an easy matter to couple the hearth tuyeres on the vacuum system, but bosh tuyeres are always placed at such a height that it is easy to adopt the arrangement in their case, and from the author's experience he would have no hesitation in advising everyone to do so, as leaks from bosh tuyeres are apt to be a good deal more troublesome than those at the hearth tuyeres.

The author's thanks are due to M. Henri Verney, St. Etienne, France; Mr. W. E. Snyder, the American Steel and Wire Company, Pittsburgh; Colonel W. Hawdon; and Messrs. F. W. Cooper, James Henderson, A. K. Reese, and P. Williams, for information promptly and most obligingly supplied and to Mr. W. H. Hallam, the author's blast-furnace foreman, for much valuable assistance in obtaining the data from which the position and size of the bosh tuyeres were decided.

GRAIN GROWTH IN METALS.*

By ZAY JEFFRIES, D.Sc., Member (Cleveland, Ohio, U.S.A.).

(*Concluded from page* 330.)

TYPICAL EXAMPLES OF GRAIN GROWTH.

I. *Grain Growth due to Strain Gradient without Temperature Gradient.*—In Professor Sauveur's experiments the heating was done in a muffle, and consequently it may be considered that during the soaking period no temperature gradient existed, that is, all parts of the specimens were at substantially the same temperature. He produced strain gradients by pressure with a Brinell hardness machine (Fig. 3, Plate XXVII), by a combination of pressure and tension in the bent bar (Fig. 4, Plate XXVII), and by tension alone (Figs. 5 and 6, Plate XXVII). He demonstrated completely that it is the degree of deformation which controls the subsequent grain growth rather than the manner in which the deformation is produced. He produced a strain gradient from the surface of the ball impression to points more remote from the contact between the ball and the specimen in Fig. 3, and the grain coarsening was due to the fact that the more severely strained portion recrystallised below 650 deg. C., and the moderately deformed portion did not recrystallise at 650 deg. C.; the boundary between these two regions permitted the formation of germinant grains. From the germinant grains to the more severely deformed portions the grains become progressively smaller as the deformation increases. This is due to the local strain gradients caused by the directional properties of the grains. This latter condition is further exemplified in his Fig. 6, Plate XXVII, which is a critically stretched bar.

Because of the directional properties of the grains themselves, it is physically impossible to deform in any manner a piece of metal composed of an aggregate of differently oriented grains and produce the same degree of strain in each grain. It is further physically impossible to deform an aggregate of differently oriented grains and produce the same degree of strain in every part of one and the same grain. These grains are surrounded by sheaths of amorphous metal which has properties different from the crystalline metal composing the grains themselves, and this discontinuity of physical properties between the grains and the material which cements them together makes it impossible to deform the interior of a grain to the same degree and in the same manner as the surface.‡ These local strain gradients will produce local recrystallisation gradients, and these in turn if the proper temperature is maintained may produce large grains; if the piece of metal has been strained by stretching these large grains will compose the whole mass of the metal after annealing at the germinative temperature, but if the total strain is different from one point to another, such as is produced by the Brinell ball impression, then the grain size will vary both in accordance with the local strain gradients and with the general strain gradient. Fig. 7, Plate XXVII, shows the progressive decrease in grain size with increasing strain in Chappell's stretched tapered bar. With a given strain gradient the temperatures near the upper range of recrystallisation will produce the largest grain size on annealing; the germinant grains will form in regions of less strain as the temperature increases. This is shown nicely in Chappell's Fig. 8, Plate XXVII. It is shown better, however, by Ruder's photographs of silicon steel, in page 329 *ante*.

What is usually considered normal grain growth results from the operation of the same laws that produce exaggerated growth. The photomicrographs (Figs. 28 to 33, Plate XXVIII, have been considered as normal examples of grain growth. It will be noted that the temperature and time of annealing have been the same in all cases, but that the amount of deformation previous to annealing has varied between 4 per cent. and 50 per cent. reduction in area. The grain size in Fig. 28, which was reduced 4 per cent. of its original area by cold rolling, is much greater than that of Fig. 33, which was reduced 50 per cent. before annealing. Numerous centres in Fig. 33 became germinative simultaneously, whereas in Figs. 28 and 29 fewer centres of germination developed. The number of germinative centres has increased as the degree of deformation increased, and this change has been progressive. Germination in these samples has been

* Part I of thesis for degree of Doctor of Science, Harvard University, Cambridge, Mass., submitted May 1, 1819. Paper read before the Institute of Metals, September 11, 1918.

† Plates XXVII and XXVIII accompanied our issue of September 20.

‡ Humfrey: "Influence of Inter-Crystalline Cohesion upon the Mechanical Properties of Metals," *Iron and Steel Institute, Carnegie Scholarship Memoirs*, 1913, vol, v, pages 86–99.

caused largely by the local strain gradients, due to the directional properties of the grains. Figs. 28 and 29 may have had strain gradients from the surface to the axis of the plates.

II. *Temperature Gradient without Strain.*—Temperature gradient alone without strain may lead to the production of coarse grains in compressed briquettes, or in metal which undergoes an allotropic transformation. The latter condition will be considered in a separate section, Figs. 9 to 18, Plate XXVII, show the action of increased resistance to grain growth, due to the addition of thoria to tungsten under constant temperature and constant temperature gradient conditions. Figs. 9 and 14 show the effect of 1 per cent. thoria added to the tungsten oxide before reducing it with hydrogen to metallic tungsten powder. The thorium oxide is not reduced with hydrogen, so it remains in the tungsten powder as non-metallic globules of ThO_2. It mechanically obstructs the coalescence of the tungsten grains. The germinative temperature of a briquette containing 1 per cent. thoria is considerably below 3,200 deg. C. All of the specimens were heated to a mean temperature of 3,200 deg. C. by electric current and held there for 12 minutes. Calculations indicate that the axis of the briquette, which was about ¼ in. square and 8 in. long, was about 150 deg. C. hotter than the surface. The temperature gradient was therefore 50 deg. C. per millimetre. The rate of heating to 3,200 deg. C. was sufficiently rapid to avoid coarsening by germination (see Figs. 9 and 14). The mean temperature was so high that grain growth took place over the whole cross-section of the briquette simultaneously and normal growth occurred. The same is true of the specimen containing 2 per cent. thoria, as shown in Figs. 10 and 15.

With 3 per cent. of thoria, however, the portion near the axis was above its germinative temperature, and the portion near the surface of the briquette was below the germinative temperature. The boundary between these two regions produced germination, and these germinant grains extended into the inert range toward the surface and then into the growth range toward the axis. Fig. 11 shows this coarse-grained structure at 20 diameters, and Fig. 16 shows a portion of one grain and the distribution of the thoria at 500 diameters. The 4 per cent. thoria sample showed the same general structure as the 3 per cent. sample, the chief difference being that germinant grains first formed nearer the axis than in the 3 per cent. sample. Fig. 12 shows the structure of the 4 per cent. thoria sample magnified 20 diameters, and Fig. 17 shows a portion of one grain and the distribution of the thoria at 500 diameters.

With 5 per cent. thoria the resistance to grain growth had so increased that under the given time and temperature conditions even the axis of the briquette was below its germinative temperature, that is, the whole of the briquette was in its inert range.

A briquette containing 5 per cent. thoria was heated so that the centre was fused, and no germinative condition was encountered. This is significant, because it illustrates that the germinative temperature can be made non-existent when the resistance to grain growth is high. Fig. 13 shows the grain size of the 5 per cent. thoria sample at 20 diameters, and Fig. 18 shows the grain size and distribution of the thoria in the same sample at 500 diameters.

When these briquettes are heated electrically with water-cooled electrode clamps, temperature gradients obtain in two directions at the ends of the briquette. There is a temperature gradient from axis to surface of the briquette, and one along the axis from the hot central portion to the cold electrode clamps. This condition has permitted the study of the history of the formation of the large grains. In the sample containing 4 per cent. thoria it was found that the portions near the cold clamps were entirely in the inert range; a little farther from the clamps the axis only was coarse grained, while in the hottest regions the whole cross-section was coarse grained.

Fig. 2, page 328 *ante*, shows the grain-size curve with different amounts of thoria after 12 minutes' exposure at a mean temperature of 3,200 deg. C. The grain size should normally decrease as the amount of thoria increases, that is, as the resistance to grain growth increases. It should correspond to the normal grain-size curve, which is shown by the broken line. The actual grain-size curve is drawn in as a continuous line, and its departure from the normal grain-size curve is entirely due to germination. It is readily seen that germinative conditions may reverse normal conditions as regards grain size in a ratio of several thousands to one. Fig. 48, × 20, page 360, shows the relative sizes of the germinant and normal grains.

Some very fine tungsten powder containing 0·75 per cent. thoria was prepared and a briquette heated to fusion with electric current. The total time of heating near the fusion temperature was about 30 minutes. Fig. 19, Plate XXVII, is a photograph at 5 diameters of a longitudinal fracture of this briquette or ingot near the electrode clamp where the temperature was low (below the melting-point) and where a sharp temperature gradient obtained. On the left of the photograph will be seen the structure in the inert temperature range, and adjacent to it in the central portion of the photograph are the large grains caused by germination; these gradually decrease in size to the right as the temperature has increased. Here again the largest grains have been produced at an intermediate temperature, and a temperature gradient was the cause of the formation of the initial germinant grains. The germinative temperature of this sample was about 2,600 deg. C. A temperature of 3,350 deg. C. (melting-point of tungsten) was reached in the hotter regions (not shown in photograph).

Another tungsten briquette from the same lot of metal was heated by electric current for 20 minutes to a mean temperature of 2,600 deg. C. The fracture is shown at 5 diameters in Fig. 20, Plate XXVII, and a polished section in Fig. 24, Plate XXVIII, at 10 diameters. It will be noted that germinant grains have formed in portions between the axis and surface of the briquette, but have not reached any considerable size. A briquette from the same metal lot was heated to the same temperature for 30 minutes. Grain growth had occurred at a faster rate during the interval from 20 minutes to 30 minutes than it had in the interval from 0 minutes to 20 minutes. The fracture in this sample is shown in Fig. 21, × 5, and a polished section in Fig. 23, × 10. We learn from this that the velocity of grain growth is small in the initial stages of germination, but that as soon as the germinant grains become large the velocity of grain growth at the same temperature becomes more rapid.

Fig. 22 shows that when one of these briquettes is heated quickly to a temperature above the germinative range the structure is fine grained, even though the time of exposure is many times greater at the higher temperature than at the germinative temperature. This sample was heated quickly to 3,200 deg. C. and held 30 minutes. Other samples have been heated for several hours at the higher temperature without producing any marked increase in grain size. The structure shown in Fig. 25 is maintained throughout the hot portion of the briquette, in this case about 8 in., but changes at the ends, due to the cold electrodes. Fig. 26 is a longitudinal section of the sample shown in Fig. 25.

Any intermediate grain size between that produced at the germinative temperature and that produced by heating quickly to a temperature above that of germination can be obtained by varying the rate of heating through the germinative range. Fig. 27 is a photomicrograph, × 10. of one of these tungsten briquettes heated in the germinative temperature range (2,600 deg. C.) for 20 minutes, and then heated for 10 minutes at 3,200 deg. C. The structure is very much coarser grained than that produced by quick heating to 3,200 deg. C., but finer grained than a sample completely coarsened at its germinative temperature. (Compare Figs. 26, 27 and 28.)

III. *Temperature Gradients in Strain-hardened Metals.*—Ruder has produced individual grains in silicon steel over 16 in. long and 1½ in. wide in comparatively thin sheets. He produced these grains by the grain-size contrast principle, which Professor Howe proposes to call "The Competitive Principle." The grains may or may not have been previously strained in order to produce large grains in this manner. Ruder's usual plan is moderately to strain the silicon steel sheet and then heat it in an electric furnace, with one end extending outside the furnace and the other end in a hot zone. Some portion of the sheet will be at its germinative temperature, and the largest grains will develop at that temperature. The hotter portions will be relatively fine-grained because heated through the germinative temperature too rapidly for coarsening to take place, and the colder portion will still be in the unrecrystallised condition. After this initial step he heats the coarse-grained portion to a high temperature and then moves the sheet through the high temperature zone of a furnace at a rate slower than that at which the large grains can absorb the smaller ones. The velocity of grain growth, of course, increases with the temperature, so that a high temperature facilitates this operation. It is not necessary to strain the whole sheet to accomplish this result. If a silicon steel sheet is produced by severe cold working followed by annealing it will be fine grained, and relatively small grains will obtain even at a high temperature. If a small section of this sheet is locally strained and then annealed at its germinative temperature, the large germinant grains should absorb with ease the normal grains composing the rest of the sheet. In this case the germinant grains may be produced by strain gradient, and then the other grains could be absorbed either by temperature gradient or grain-size contrast without temperature gradient or by any combination of the two.

A metal can be strain-hardened so severely that the local strain gradients, which must be present, will produce more germinant centres than the number of equilibrium grains at the temperature of recrystallisation. No marked grain coarsening could take place under these conditions without a temperature gradient.

Fig. 34, Plate XXVIII, is a typical structure of tungsten worked below its recrystallisation temperature. There is substantially no strain gradient from surface to axis of the rod, and the local strain gradients due to the directional properties of the grains are such that germinant grains form very close together. A tungsten rod with this structure when heated to any uniform temperature recrystallises in all parts at about the same rate, resulting in a structure of uniform and small grains. When a tungsten rod 0·080 in. diameter having a fibrous structure is heated by electric current it is possible to maintain the portion near the axis of the rod above its recrystallisation temperature while the surface is below it. Germinant grains will form at the boundary between these two regions, and it is possible to develop coarse-grained structures in this manner. Also when a tungsten rod is heated considerably above that of recrystallisation some portions near the clamps will be at their germinative temperatures. Coarse grains will develop in accordance with the time of heating under these conditions. An example is shown in Fig. 35, Plate XXVIII *ante*.

Figs. 38 and 39, Plate XXVIII, show the effect of rate of heating through the germinative temperature range on he grain size of 0·080 tungsten rods. If the recrystallisation temperature is passed rapidly the temperature gradient produced by the direct electric heating does not have time to form germinant grains, and consequently normal grain growth occurs. On the other hand, if the rate of heating through the germinative temperature range is slow, large grains, such as are shown in Fig. 39, may be produced.

The same conditions obtains in small wires, as shown in Figs. 36 and 37. These are photographs of quickly heated and slowly-heated 0·007 in. diameter tungsten wires. It will be noted that the rapidly-heated samples are fine grained, whereas the slowly-heated samples are coarse grained. The time in which these large grains develop is extremely small. Ten seconds is ample to produce the coarse grains shown in Fig. 39. On the other hand, the fine-grained structure shown in Fig. 38 does not change materially even after 10 hours' exposure at a temperature near the melting-point of tungsten. The rate of heating such wires in a muffle with no temperature gradient would have but little effect on the grain size.

The same general laws apply to other metals. It is easier to maintain a sharp temperature gradient in a metal at a high temperature than at a low temperature. Therefore this phenomenon will be most marked in such metals as tungsten and molybdenum, which recrystallise at high temperatures.

When tungsten is worked a moderate amount, and a general strain gradient obtains from the surface to the axis of the rod, it coarsens by germination on uniform heating in the same manner as the other metals. When it is heated by electric current, however, it is difficult to coarsen. The temperature gradient produced by the electric current counterbalances the strain gradient produced by the deformation. The strain greatest at the surface of the rod, and hence the recrystallisation temperature, is less at the surface than at the axis. The temperature at the surface of the rod is also less when it is heated by electric current, so that the recrystallisation temperature of the axis and surface are reached at about the same time.

IV. *Change in Grain Size at Allotropic Points.*—Stead has demonstrated (see Fig. 40, page 359) that iron coarsened below 900 deg. C. has its grain refined by heating above 900 deg. C., followed by either slow or rapid cooling. This grain refinement does not require previous deformation. On heating iron past 900 deg. C. it changes from the non-gamma to the gamma condition with a change in crystal form; both crystal forms are in the isometric system, but a change is effected in the position of the atoms. This action is reversed upon cooling from above to below 900 deg. C. 900 deg. C. is in a region of rapid grain growth in iron. If we assume that iron changing from the non-gamma to the gamma condition passes through a chaotic state as regards its crystal form, we have conditions obtaining at the time of transformation similar to the recrystallisation of a cold-worked metal, or the rapid grain growth at the proper temperature of a briquette of compressed metal. The grain size of the new allotrope will depend largely on: (*a*) The rate of heating or cooling through the transformation range, and (*b*) the temperature gradient obtaining during the transformation period.

These facts have been demonstrated experimentally. Stead and Carpenter* have shown that electrolytic iron when quenched from above 900 deg. C. has a smaller grain size than when cooled slowly through the transformation range. They also show that the grain size varies with the temperature gradient obtaining during the transformation, and they have produced elongated grains by means of a temperature gradient. Fig. 41 page 359, is a good example of the result of temperature gradient during the transformation of gamma to non-gamma iron.

Other conclusions are also discussed in a series of papers and discussions.† The grain size of one allotrope influences the grain size of the allotrope into which it transforms; in general, the larger the grain size of one allotrope the larger will be the grain size of the allotrope into which it transforms. This may be called the normal condition, but temperature gradients at the time of transformation may produce germinative conditions which reverse the order of grain size, in much the same manner that germination after strain hardening or temperature gradients in compressed metals reverse the grain size from what would normally be expected.

The change from one allotrope to another takes place most readily at the grain boundaries, and the new modification does not have the same boundary lines (even if they should be the same size, which is unusual) as the grains in the old modification. Neither is the orientation of the grains in the new modification inherited from the old modification. A grain must transform from at least one nucleus, but usually transforms from several nuclei. Since the nuclei first form at the grain boundaries it follows that a fine-grained allotrope should transform into a fine-grained new modification, because a fine-grained structure has more grain boundary surface than a coarse-grained one. This gives rise to the general rule that the grain size of one allotrope influences to a certain extent the grain size of a new modification into which it transforms.

If the grain size of the new allotrope immediately on transformation is less than the equilibrium grain size for the time, temperature, and temperature gradient conditions obtaining at the time of transformation, grain growth will take place until equilibrium grain size is

* "The Crystallising Properties of Electro-Deposited Iron," *Journal of the Iron and Steel Institute*, No. 11, 1913, pages 119 to 170.

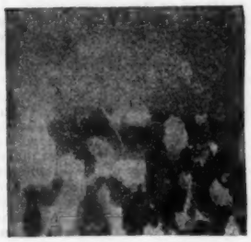
† Howe: "The Supposed Reversal of Inheritance of Ferrite Grain Size from that of Austenite," *Bulletin of the American Institute of Mining Engineers*, No. 129, September, 1917, pages 1365 to 1367. Discussions by Ruder, *idem*, January, 1918, pages 105 to 106. Jeffries: "Grain size Inheritance in Iron and Carbon Steel," *idem*, November, 1917, pages 1883 to 1899. Discussions by Ruder and Jeffries, *idem*, April, 1918, pages 727 to 734.

established. Since a fine-grained structure would be more favourable to the formation of large grains by germination during a transformation than a coarse-grained structure, Ruder's results, shown in Figs. 42 and 43 on this page, can be explained by assuming germination in Fig. 42 and a normal transformation in Fig. 43. The germination in Fig. 42 was promoted by the small grain size immediately after transformation, whereas the comparatively large grain size immediately after transformation in Fig. 43 was stable under the particular conditions of furnace cooling used by Ruder. A good many results indicate that the equilibrium grain size of non-gamma iron just below 900 deg. C. is greater than the equilibrium grain size of gamma iron between 900 deg. C. and 1,050 deg. C. It is very significant that the tensile strength of non-gamma iron just below 900 deg. C. is about the same as that of gamma iron at about 1,050 deg. C.* Mobility in the atoms of a metal vary inversely as the cohesion, so we may assume that non-gamma grains would be produced, such as Stead and Carpenter and Ruder have reported.

When gamma iron is heated to very high temperatures—say, above 1,200 deg. C.—very large grains are produced which transform on cooling past 900 deg. C. into comparatively large grains of non-gamma iron (though smaller than the non-gamma iron grains), which are not favourable to coarsening by germination. There may be fewer nuclei of transformation under these conditions than the equilibrium number of grains of the non-gamma iron under the particular conditions of cooling, and therefore a grain size would be produced larger than that produced by cooling fine-grained gamma iron through the transformation range.

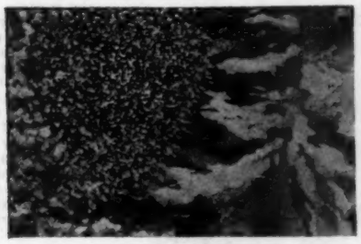
Fig. 44 is a photograph, × 100, of Armco iron heated to 1,300 deg. C. for 2 hours and then cooled slowly to room temperature in the furnace. The grain size is larger than the equilibrium grain size of non-gamma iron just below 900 deg. C. for the conditions obtaining

FIG. 40.



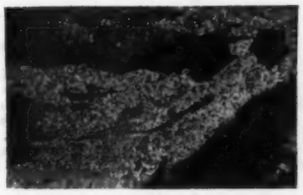
Upper portion heated above, lower portion below, Ac_3 and quenched full size. *Stead.*

FIG. 41.



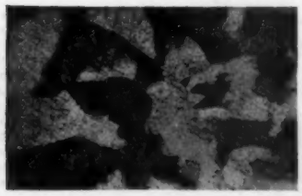
Electrolytic Iron. Right heated above, centre kept below, Ac_3. Cooled in air. × 4. *Stead & Carpenter*

FIG. 42.



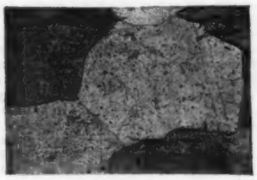
Pressed electrolytic iron heated 3 hr. at 1,000° C. and furnace cooled. × 50. *Ruder.*

FIG. 43.



Same as Fig. 42. Heated 3 hr. at 1,250°–1,300° C. and furnace cooled. × 50. *Ruder.*

FIG. 44.



Armco Iron heated 2 hr. at 1,300° C. and furnace cooled. × 100.

FIG. 45.

Armco Iron heated 2 hr. at 1,300° C. and quenched in water. × 100.

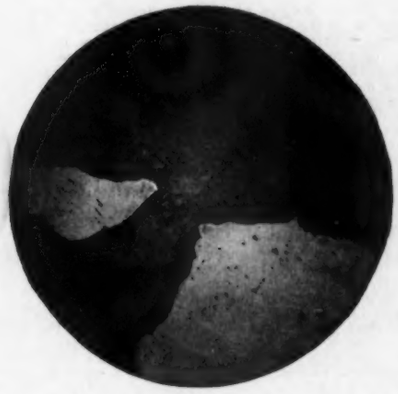
EFFECT OF ALLOTROPY ON THE GRAIN SIZE OF IRON

Reduced by one-third.

FIG. 46.

Fine-grained tungsten ingot with centre fused and resolidified. Each small grain has not served as nucleus for crystallization of molten metal. × 20.

FIG. 47.



Coarse-grained tungsten ingot with centre fused an.. resolidified. Each grain has served as nucleus for crystallization of molten metal. × 25.

Reduced by one-sixth.

The time of cooling to room temperature after the ingot fused was only about 1 minute, so the rate of solidification must have been very rapid. Fig. 46 is a photograph at 20 diameters of this sample. At the time the liquid tungsten was in contact with the fine-grained solid tungsten, we would expect solidification to begin from each of these differently oriented grains, and we should further expect that each grain would force its own orientation on the solidifying portions. Solidification probably did begin in this manner, but some of the nuclei were much more active than their neighbours, probably due in part to a favourable orientation which would permit the dendritic arms to extend radially toward the axis of the ingot and in part to larger size. These more active grains have not only controlled the atoms of the molten metal more remote from the original boundary between molten and solid metal, but they have actually absorbed by grain growth the portions which initially solidified on other grains. This teaches us that grain

the mobility of the atoms of gamma iron is less between 900 deg. C. and 1,050 deg. C. than in non-gamma iron just below 900 deg. C. The mobility of the atoms also determines the velocity of grain growth as well as the size of the equilibrium grains under given conditions.

When non-gamma iron transforms into gamma iron, according to the general rule of more nuclei than grains, more grains of gamma iron will form than there were grains of non-gamma iron. A grain refining will result, because even if grain growth takes place in the gamma iron the grains will not be larger than the equilibrium grain size, unless germinative conditions have obtained. As the temperature of the gamma iron is increased from 900 deg. to 1,050 deg., the grains should gradually grow until a grain size equal to that of the non-gamma iron before transformation existed. Ordinarily, then, if gamma iron at any temperature between 900 deg. C. and 1,050 deg. C. is cooled to non-gamma iron, the grain size of the latter should not vary unless germinative conditions obtain. The grain size should be the normal grain size of non-gamma iron under the given conditions of cooling. If germinative conditions obtain then large during cooling. The grains are also about 20 times smaller than would be expected in the gamma iron after a 2-hour sojourn at 1,300 deg. C. Fig. 45 is a photograph, × 100, of the same sample heated 2 hours at 1,300 deg. C. and then quenched in water. The difference in grain size between Figs. 44 and 45 is entirely due to the difference in rate of cooling through and slightly below the transformation temperature.

Grain Growth in Cast Metals.—No grain growth takes place in a cast metal in the solid state unless a new allotrope forms in the grain growth region. For example, pure iron in the cast state would undergo grain size changes at 900 deg. C., but the grain structure of pure cast silver could not be changed by heating alone below the melting-point. If the grains are deformed, heating will then cause recrystallisation in the usual way. When a liquid metal is cooled quickly past its freezing-point it has a smaller grain size than when cooled slowly past its freezing-point.* No matter how it is cooled or what its grain size after solidifying, no grain growth takes place by heating alone in the solid state. The following experiments throw some light on this question.

A fine-grained tungsten briquette or ingot was heated by electric current until the central portion was fused.

Another tungsten ingot was produced in the coarse-grained condition and its centre was fused, as shown in Fig. 47. When it resolidified each of the old grains served as a nucleus for the solidification of the molten tungsten. There were, however, so few nuclei in this case that each was stable under the conditions of cooling.

From the above experiments we may conclude that the grain size established during the solidification of a metal even in the short time of a fraction of a minute may be more balanced so far as grain-size contrast and other conditions resisting further grain growth are concerned, than in a worked and annealed metal after many hours' sojourn at a temperature slightly below the melting-point.

Macro-Mechanism of Grain Growth.—There are two opinions regarding the mechanism of grain growth. First, that grain coalescence either involves the absorption of a whole grain by another or none of it; and, second, that grain growth takes place by boundary migration.

A superficial examination would indicate that either a grain was entirely absorbed or none of it was absorbed by an adjacent grain, because if grain growth takes place by boundary migration we would expect some of the growth is extremely rapid during the solidification of a metal, and that the grain size of a casting is not alone dependent upon the number of nuclei from which crystallisation begins, but is largely dependent upon the rate of grain growth during solidification.

*Rosenhain and Humfrey: "The Tenacity, Deformation and Fracture of Soft Steel at High Temperatures," *Journal of the Iron and Steel Institute*, No. I, 1913, pages 219 to 314.

*This general rule is reversed in certain alloys composed of two constituents.

grains to decrease while others increased in size. If a metal is examined under the microscope and then heated to a high temperature so as to produce grain growth, and then examined again, it cannot be observed that any of the grains become smaller, but particular grains either look larger or the same size as previously. Some experiments indicate that when a grain begins to be absorbed by other grains its complete absorption is accomplished in a very short time.

Experiments conducted under the writer's direction at the Case School of Applied Science, Cleveland, Ohio, by H. H. Smith and R. E. Widener, have demonstrated conclusively that grain growth takes place by boundary migration. Samples of Armco iron were marked, photomicrographs were made, and the samples were then heated to 800 deg. C. in an atmosphere of hydrogen a sufficient time to cause grain growth. The samples were polished slightly, re-etched and photographs were taken of the marked areas. The grain boundaries of the same areas on both negatives were drawn by projection on paper, one set being traced with black and the other with red ink. The grain boundaries after heating did not conform to the boundaries before heating. Grain growth had taken place by boundary migration.

Another independent observation leads to the same conclusion. If a photograph of a fine-grained metal is made and the metal then heated to cause grain growth and another photomicrograph of the same area is taken, it will be found impossible to reproduce the structure of the second photograph by following the grain boundaries on the first. If the grain boundaries did not migrate this would be possible.

Micro-Mechanism of Grain Growth.—Having established the fact that grain growth takes place by boundary migration, let us consider an aspect which is now more or less theoretical, namely, the manner in which the boundary migrates.

Let us first consider the normal growth of unstrained grains. There is assumed the validity of the amorphous theory which postulates that the grains of crystalline material are completely surrounded by thin films of the same metal in the amorphous condition; that is, amorphous metal is the material which cements the grains together, and consequently it is the material which gives continuity to the system. While the amorphous material has properties different from the crystalline, the atoms composing the two are of the same nature, and one phase can be changed into the other by changing the arrangement of the atoms.

The author has shown that the cohesion of the amorphous phase of a metal is the same as that of the crystalline phase at the lowest recrystallisation temperature;* that in the whole region of grain growth in the solid state the amorphous phase is softer—that is, less cohesive—than the crystalline phase, and that the amorphous phase decreases in cohesion with increase in temperature at a faster rate than the crystalline phase. This indicates that both the amorphous and crystalline phases must reach a condition of considerable mobility before grain growth can take place, but that the cohesion of the crystalline phase must be greater than that of the amorphous phase.

The chief characteristic of the crystalline phase is the organisation of the atoms into a regular arrangement. The arrangement of the atoms of the amorphous phase is probably haphazard, but at the junction between amorphous and crystalline metal the change from regular to haphazard arrangement may be gradual.†

The thickness of the amorphous cement between two adjacent differently oriented grains should depend on the size of the grains and their particular orientations. Under any given condition there must be an equilibrium thickness of the amorphous film due to the crystallic attractions in different directions and to surface tension.

We know that in some way the amorphous material between two grains is changed to the crystalline state and added to the growing (larger) grain, and that some of the crystalline material in the attacked (smaller) grain is changed into the amorphous condition. How does the size of a grain influence its power of attack?

The atoms in the interior of a grain must have some influence on the attractive powers of the surface atoms. This cumulative attractive force can be accounted for in a simple manner. Parsons'‡ idea of the structure of the atom accounts for so many of the observed phenomena that we will consider his type of atom. It is cubical; each atom has a small magnetic moment. When a group of atoms arrange themselves in a regular manner to form a crystal, each atom adds its bit to the magnetic moment. The total magnetic force will therefore be proportional to the number of atoms in the same arrangement, which in turn determines the size of a grain. This magnetic force will be greatest at the surface atoms, for the same reason that an ordinary magnet has the greatest field of force at its ends.

The atoms in the amorphous phase, being oriented in a random manner, will have greater vibrational energy than those in the crystalline phase, but each atom will act as a unit as regards its magnetic moment. It is logical to suppose that when the temperature of a metal is such that grain growth occurs, the magnetic force of the surface atoms of a large grain will force an atom of the amorphous material into the regular arrangement. When this is accomplished the atom is no longer amorphous, but has become part of the crystalline system. In changing from the amorphous to the crystalline state, each atom liberates a certain amount of heat of crystallisation which will be available partly to increase the energy of the other amorphous atoms, and partly to increase the energy of the growing grain. The energy of the growing grain is increased by the addition of another atom.

We must assume that before an atom of amorphous material has been changed to crystalline there was substantial equilibrium between the amorphous and crystalline phases, and this equilibrium demanded a certain thickness of the amorphous film. Having disturbed this equilibrium by a condition which would cause grain growth, namely, slight increase in temperature or slight increase in time at a given temperature, and having given the amorphous atoms added energy caused by the heat of crystallisation, will not their excess vibration due to this added energy amorphise an atom of the smaller and hence weaker adjacent grain? If this

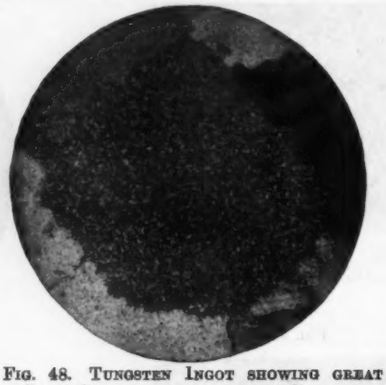


FIG. 48. TUNGSTEN INGOT SHOWING GREAT GRAIN SIZE CONTRAST BETWEEN GERMINANT AND NORMAL GRAINS. GRAINS IN CENTRE ARE NORMAL. × 20.

FIG. 49. SMALL GRAIN ENCLOSED IN LARGE GRAIN. × 500. REDUCED BY ONE-SIXTH.

is the mechanism of transfer of one atom of the amorphous metal to the larger grain and the transfer of another atom from the smaller grain to the amorphous metal, this process needs only to be repeated as many time as there are atoms to transfer to account for all grain growth.*

That the atoms of crystals are arranged in a regular manner is conclusively shown by Bragg and Bragg.† A new method for the determination of the positions of the atoms in crystals has been developed by Hull.‡ He considers the four arrangements of the atoms of the isometric system, namely, the simple cube, centred cube, face centred cube, and diamond lattice. While each of these systems represent different arrangements they all represent regular arrangements, and this should cause cumulative magnetic moment. I am indebted to Professor H. P. Hollnagel for valuable suggestions in connection with this hypothesis.

Force of Grain Growth in Strain-Hardened Metals.—According to Beilby's amorphous theory in strain-hardened metals, the deformation generates amorphous metal in the interior of the grains. Deformation takes place by the slipping of fragments of the grain along the cleavage or gliding planes. When one portion of the grain is thus separated from other portions by a film of amorphous material the grain no longer acts as a unit either in attack or defence as regards grain growth, but each fragment sheathed or partly sheathed in an amorphous film acts as a unit. This would naturally follow from the previous discussion.

A small grain which is not strain-hardened and which abuts a large strain-hardened grain may absorb it, because the fragments of the strain-hardened grain may be much smaller than the unstrain-hardened grain.

It is not yet known definitely what the micro-mechanism of recrystallisation is.* It is known that a strain-hardened grain can be heated to its recrystallisation temperature, and it will change into several smaller equiaxed grains. Since these equiaxed grains have different orientations it follows that at least some of them are oriented differently from the original strain-hardened grain. This can be explained in a simple manner if it is assumed that the deformation leaves various portions of a strain-hardened grain differently oriented. We know this is the case when a grain is bent, because it is impossible to bend a grain without changing the relative orientations of its various parts. We also know that twisting a grain changes its internal orientation. While it is not known that rolling or wire-drawing or hammering a metal leaves different portions of a given deformed grain in different orientations, it is known that the recrystallising properties of grains deformed by pressure or tension in a single direction are substantially the same as those deformed by bending or twisting.

The Effect of Thickness on Grain Growth.—It has been observed by Stead and Carpenter on electrolytic iron, by Ruder on silicon steel, and by the writer on tungsten that the thickness of a piece of metal affects grain growth. Certain thicknesses seem to be favourable for the production of germinative conditions with the consequent production of coarse-grained structures. Stead and Carpenter, for example, found that a thickness of 0·010 in. to 0·012 in. was the most favourable to the production of large grains in electrolytic iron cooled slowly past 900 deg. C. Ruder has obtained this coarsening, however, with much thicker pieces, so it is evident that some factor besides thickness helps to control this action. More data is needed on this subject before general deductions can be made.

Small Grains included within Large Grains.—This subject has been discussed briefly by Ruder and Jeffries, and more extensively by Howe.†

During the rapid absorption of small grains by germinant grains it sometimes happens that certain grains will not be absorbed but will keep their identity, although completely surrounded by the large grains. The writer has called attention to the fact that once these small grains are isolated within a larger grain their resistance to coalescence seems to be increased. He at first attributed the reason for this to a balancing of the crystallic forces, but he now has a much simpler explanation.

Grain growth causes a general decrease in the volume of a metal supposedly due to a lessening of the amount of amorphous metal which occupies more volume than the crystalline metal to which it changes. The grain-growth range is entirely in the region in which the amorphous phase is more or less plastic and actually weaker than the crystalline phase. Any change in volume of a given mass of metal composed of an aggregate of small grains can be accommodated easily by flow in the amorphous metal surrounding the grains.

On the other hand, when a grain has been isolated within a larger one the volume shrinkage which would result if coalescence could take place would either disturb the atoms composing the large grain or leave a cavity within it after coalescence. We would hardly expect the forces of grain growth to be great enough to produce either of these results, and it seems that they are not, especially at temperatures well below the melting-point. This accounts for the high resistance to grain coalescence after the small grain has been surrounded by the larger one. It does not explain, however, why a particular grain is not absorbed by the larger one before isolation. Of course the smaller grain must have had a greater resistance to coalescence than its neighbours. It may have been considerably larger, as indicated in the writer's previous remarks, or it might have had an especially large amount of foreign obstruction material at its boundary. Professor Howe discusses this phase and suggests an additional cause for high resistance to grain growth, namely, that the isolated small grains seem to have approximately the same orientation, which may be unfavourable to coalescence. The writer has examined some of Ruder's photomicrographs of large grains of silicon steel and he finds that the isolated grains do not all have the same orientation. Furthermore, he has examined grains of other metals which had been formed by the coalescence of at least 50,000,000 smaller grains, and these did not have isolated grains. It would seem that a few grains out of 50,000,000 would have had orientations favourable to resisting growth.

THE ELECTRIC WELDING OF OIL TANKS.—We read in *The Iron Age* that electric arc welding is being substituted for riveting in the manufacture of oil tanks 35 ft. long and 6 ft. to 8 ft. in diameter, made of ¼in. plate, by the Kansas City Structural Iron Company, Kansas City, Mo. This company recently installed a 150-ampere Lincoln arc welder for this purpose.

* "The Amorphous Metal Hypothesis and Equicohesive Temperatures," *Journal of the American Institute of Metals*, No. 3, December, 1917, vol. xi, pages 300 to 324.

† Humfrey: "Influence of Inter-crystalline Cohesion upon the Mechanical Properties of Metals," *Iron and Steel Institute, Carnegie Scholarship Memoirs* 1913, vol. v, pages 86 to 99.

‡ "A Magneton Theory of the Structure of the Atom" *Smithsonian Institute, Miscellaneous Proceedings*, No. 4, 1916, vol. lxii.

* Compare with Rosenhain, *Internationale Zeitschrift fur Metallographie*, December, 1913, pages 98 to 103.

† "X-Rays and Crystal Structure, 1916," *Journal of the Institute of Metals*, No. 2, 1916, vol. xvi, pages 2 to 13.

‡ "A New Method of X-Ray Crystal Analysis," *Physical Review, N.S.*, No. 6, December, 1917, vol. x, pages 661 to 696.

* Edwards: "Mechanical Crystal Twinning by Direct Mechanical Strain," *Journal of the Institute of Metals*, No. 2, 1915, vol. xiv, pages 116 to 144. Howe: "Recrystallisation after Plastic Deformation," *Transactions of the American Institute of Mining Engineers*, 1916, vol. lvi, pages 561 to 570.

† *Revue de Métallurgie*, No. 2, vol. xv, pages 137 to 172.